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LONG RANGE SEISMIC MEASUREMENTS

# GREELEY

20 DECEMBER 1966

Prepared for

AIR FORCE TECHNICAL APPLICATIONS CENTER

Washington, D. C.

28 APRIL 1967

By

TELEDYNE INC.



Under

Project VELA UNIFORM

Sponsored By

ADVANCED RESEARCH PROJECTS AGENCY

Nuclear Test Detection Office

ARPA Order No. 624

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LONG RANGE SEISMIC MEASUREMENTS

GREELEY

20 December 1966

SEISMIC DATA LABORATORY REPORT NO. 180

| | |
|---|---|
| AFTAC Project No.: | VELA T/6702 |
| Project Title: | Seismic Data Laboratory |
| ARPA Order No.: | 624 |
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| Name of Contractor: | TELEDYNE, INC. |
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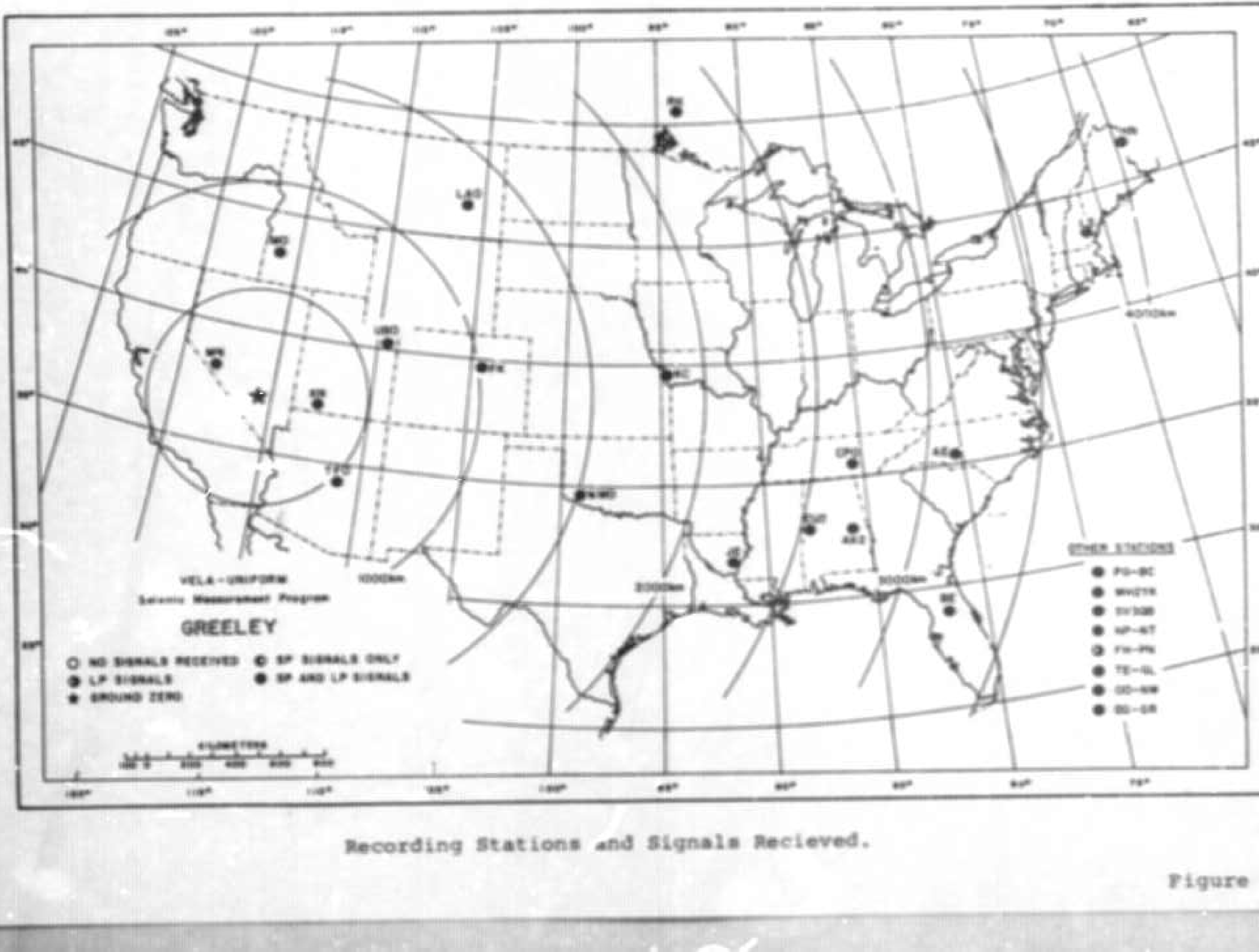
GREELEY

EVENT DESCRIPTION

| | |
|---|---|
| DATE: | 20 December 1966 |
| TIME OF ORIGIN: | 15:30:00.1Z |
| YIELD: | |
| MAGNITUDE: | 6.29 ± 0.45 |
| LOCATION: | |
| SITE: | Nevada Test Site, Area U20g |
| | GEOGRAPHIC COORDINATES: |
| | Lat: 37°18'07.0" N |
| | Long: 116°24'30.0" W |
| ENVIRONMENT: | |
| | GEOLOGIC MEDIUM: ZEOLITIZED TUFF |
| | SURFACE ELEVATION: 6470 ft. |
| | SHOT ELEVATION: 2430 ft. |
| | SHOT DEPTH: 4040 ft. |
| COMPUTED EPICENTER: | |
| | ALL STATIONS |
| | GEOGRAPHIC COORDINATES: |
| | Lat: 37°14'56.4" N |
| | Long: 116°31'44.4" W |
| | TIME OF ORIGIN: 15:30:00.4 |
| | DEPTH CONSTRAINED TO: 0 km |
| | EPICENTER SHIFT: 12.2 km, S 61° W |




Recording Stations and Signals Recieved.

Figure 1

INTRODUCTION

A long range seismic measurements (LRSM) program and several larger seismographic observatories were established under VELA-UNIFORM to record seismological data resulting from natural seismic activity and a planned series of U. S. underground nuclear tests. The LRSM teams are mobile and occupy locations selected to provide optimum data from events of special interest; the observatories are permanent installations as follows:

Wichita Mountains Seismological Observatory (WMSO)
Lawton, Oklahoma

Uinta Basin Seismological Observatory (UBSO)
Vernal, Utah

Cumberland Plateau Seismological Observatory (CPSO)
McMinnville, Tennessee

Tonto Forest Seismological Observatory (TFSO)
Payson, Arizona

Large Aperture Seismic Array (LASA)
Billings, Montana

The purpose of this report is to provide an analysis of data resulting from the GREELEY event recorded by the LRSM teams and the VELA observatories and a preliminary summary of data reported by other permanent and temporary seismographic stations.

## INSTRUMENTATION AND PROCEDURE

The instrumentation at each of the LRSM locations consists of three-component short-period and three-component long-period seismographs. In general, data are recorded on 35 millimeter film and on one-inch 14 channel magnetic tape, although recently more portable instrumentation has been incorporated which records only on magnetic tape. The stations are all equipped to record WWV continuously to provide accurate time control and calibration is accomplished once each day and just prior to each shot at the operational settings. Pertinent information useful for analysis of LRSM data is available to qualified users of this data and is contained in Technical Report 65-43, "Interpretation and Usage of Seismic Data, LRSM program." General information on LRSM van and portable system equipment and operation is given in Technical Report 66-27, "The LRSM Mobile Seismological Laboratory," and 65-74, "A Portable Seismograph." Copies of these reports may be obtained from DDC. The AD control number of Technical Report 66-27 is 480343. All the observatories have both long-period and short-period, three-component instrumentation, in addition to their other specialized facilities.

Station information is presented in Appendix I. This includes the station name and code; the geographic coordinates,

distances and azimuths involved; the station elevations; and the type of instruments in use at each location. Representative instrumental response curves are shown in Appendix II(B) and II(C).

The procedures used in measuring amplitudes reported herein are illustrated in Appendix II(A) and the unified magnitude is calculated as shown in Appendix I(B). The distance factors (B) beyond 16° are from Gutenberg and Richter*. For distances less than 16° values were read from a curve in the Gutenberg and Richter paper back to 10° and then extrapolated to 2°, using an inverse cube relationship. An additional magnitude for less than 16° was computed using a method described by Evernden**. (Figure 3).

A standard hypocenter location program for a digital computer is used to determine the location using data from all stations analyzed. Best-fit values of latitude, longitude, and time of origin are determined statistically by a least squares technique. This utilizes a Jeffreys-Bullen travel-time curve as modified by Herrin in 1961 on the basis of Pacific surface-focus recordings. Precision of the computation is limited primarily by the accuracy of arrival times, the validity of the standard travel-time curve, and by local velocity deviations. This method is based on P-wave



* Gutenberg, B. and Richter, C. F., Magnitude and Energy of Earthquakes, Ann. Geofis., 9 (1956), pp. 1-15

** Evernden, J. F., Magnitude Determination at Regional and Near Regional Distances in the United States, AFTAC/VELA Seismological Center Technical Report VU-65-4A, (1965), pp.6, 13

arrivals with the depth constrained to zero.

## DATA AND RESULTS (LRSM AND VELA OBSERVATORIES)

The parameters of the GREELEY event and a summary of the seismic evaluation is shown on the Event Description page. The operational status of the 26 LRSM stations and observatories is given in Table 1 and illustrated in Figure 1.

Table 2 summarizes the measurements made of the principal phases from the GREELEY event at the LRSM and VELA stations. Included are the Pn and P arrival times, the maximum amplitudes (A/T) of Pn or P motion and other phases as seen on the short-period vertical instruments. Long-period Love and Rayleigh wave motion are also tabulated in (A/T) form. In addition, individual station Rayleigh wave areas ($mm^2$) is indicated as measured on the LPZ only. Although reduced to 1K magnification, they have not been normalized to any magnitude. Twenty-five stations recorded short-period signals. Long-period signals from this event were recorded by 26 stations.

The unified magnitudes determined from the LRSM and VELA observatories is shown in Figure 2. The average magnitude is 6.29 $\pm$ 0.45. The adjusted magnitude is 6.16 $\pm$ 0.40 and is shown in

Figure 3.

The travel-time residuals from the Pn and P phases are shown in Figure 4. Figures 5 through 9 illustrate plots of the amplitudes of P, Pg, Lg, LQ, and LR.

Attached to the report are illustrative seismograms showing the signals recorded at 4 stations. The most distant station analyzed that recorded GREELEY was GG-GR at a distance of 9095 kilometers.

Principal Phases
GREELEY
20 December 1966
15:30:00.12

| Code | Station | Distance (km) | Inst. | Magnification (k) Film x 10 | Phase | Observed Travel Time (min) | Observed Travel Time (sec) | Period T (sec) | Maximum Amplitude A/T | Magnitude mb | Magnitude Ms | Area ($mm^2$) LPZ |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| MN-NV | Mina, Nevada | 190 | SPZ | 0.17 | Pn | 0 | 31.7 | 0.4 | 26590 | 4.62 | 6.25 | |
| | | | SPZ | 0.048* | Pg | 0 | 33.1 | 0.4 | 170750 | | | |
| | | | SPT | 0.176 | Lg | | | 1.0 | 100975 | | | |
| | | | LPT | | LQ | | | --- | --- | | | |
| | | | LPZ | 0.0376 | LR | | | (9.5) | (4240941) | | | 142,245.99 |
| KN-UT | Kanab, Utah | 320 | SPZ | 0.116 | Pn | 0 | 47.0 | 0.4 | 4632 | 6.90 | 6.44 | |
| | | | SPZ | 0.116 | P, | 0 | 53.7 | 0.55 | 74170 | | | |
| | | | SPT | 0.142 | Lg | | | 1.2 | 131000 | | | |
| | | | LPT | | LQ | | | --- | --- | | | |
| | | | LPZ | 0.0495 | LR | | | (1.7 | 88101 | | | 11,333.33 |
| TFSO | Tonto Forest Observatory, Arizona | 572 | SPZ-60 | 2.0 | Pn | 1 | 19.7 | (0.4) | (1120) | (6.40) | (6.36) | |
| | | | SPZ-60 | 2.0 | (PP) | 1 | 27.1 | 0.5 | 2032 | | | |
| | | | SPZ-60 | 10.7* | Pg | 1 | 35.2 | 0.7 | 5214 | | | |
| | | | SPN | 1.00 | Lg | | | (1.0) | (10637) | | | |
| | | | SPE | 1.00 | Lg | | | (1.2) | (4493) | | | |
| | | | LPN | 0.125 | LQ | | | 13.0 | 2542 | | | |
| | | | LPN | 0.125 | LQ | | | (13.0) | (1464) | | | |
| | | | LPZ | 7.09 | LR | | | 15.0 | 14933 | | | 7,305.56 |
| MO-ID | Mountain Home, Idaho | 641 | SPZ | 2.73 | Pn | 1 | 28.4 | 0.7 | (730) | (5.95) | (5.63) | |
| | | | SPZ | 2.73 | e | 1 | 30.4 | 0.9 | 1155 | | | |
| | | | SPZ | 2.73 | e | 1 | 32.0 | 1.0 | 2060 | | | |
| | | | SPZ | 2.73 | PP | 1 | 35.1 | 0.8 | 1490 | | | |
| | | | SPZ | 2.73 | Pg | 1 | 46.5 | 1.0 | 29306 | | | |
| | | | SPT | 0.915* | Lg | | | 1.1 | 33737 | | | |
| | | | LPT | 0.135* | LQ | | | 11.0 | 36301 | | | |
| | | | LPZ | 0.146* | LR | | | 12.0 | 9170 | | | 2,958.80 |
| UBSO | Uinta Basin Observatory, Utah | 682 | SPZ-10 | 0.4 | Pn | 1 | (35.0) | 1.0 | 2750 | 7.20 | 7.13 | |
| | | | SPZ-10 | 0.4 | Pg | 1 | 53.3 | (0.6) | (7000) | | | |
| | | | SPN | 0.666 | Lg | | | 1.4 | 13967 | | | |
| | | | SPE | 0.50 | Lg | | | 1.4 | 7300 | | | |
| | | | LPN | 0.3* | LQ | | | 15.0 | 9000 | | | |
| | | | LPE | 0.51* | LQ | | | 15.0 | 5106 | | | |
| | | | LPZ | 2.1* | LR | | | 17.0 | 995 | | | 1,097.14 |
| FR-CO | Franktown, Colorado | 1073 | SPZ | 29.9 | Pn | 2 | 22.6 | 0.8 | 636 | 7.19 | 5.71 | |
| | | | SPZ | | Pg | 3 | (03.4) | --- | --- | | | |
| | | | SPT | | Lg | | | --- | --- | | | |
| | | | LPT | 0.658 | LQ | | | (13.0) | (30360) | | | |
| | | | LPZ | 0.156 | LR | | | 13.0 | 7338 | | | 3,441.54 |
| LAO | Dubberry, [NO-10] Montana | 1340 | SPZ | | Pn | 3 | 12.5 | -- | --- | | | |
| | | | LPZ | 2.16 | LR | | | 17.0 | 935 | | | 812.50 |
| WMSO | Wichita Mountain Observatory, Oklahoma | 1429 | SPZ-6 | 7.0 | P | 3 | 30.4 | 1.5 | 1429 | 6.56 | 6.30 | |
| | | | SPZ-6 | 7.0 | e | 3 | 53.7 | 1.4 | 817 | | | |
| | | | SPZ-6 | 7.0 | (Pg) | 4 | 34.7 | 1.1 | 2097 | | | |
| | | | LPN | 2.0 | S | 6 | 20 | 15.0 | 238 | | | |
| | | | LPE | 2.0 | S | 6 | 10 | 15.0 | 348 | | | |
| | | | SPN | 6.0 | Lg | | | 1.9 | 3000 | | | |
| | | | SPE | 6.0 | Lg | | | 1.6 | 1302 | | | |
| | | | LPN | 1.0* | LQ | | | (15.0) | (7000) | | | |
| | | | LPZ | 0.36 | LR | | | 16.0 | 5563 | | | 3,750.00 |
| KC-MO | Kansas City, Missouri | 1717 | SPZ | 11.8 | P | 4 | 41.4 | 1.1 | 976 | 5.80 | | |
| | | | SPZ | 11.8 | e | 4 | 07.3 | (1.1) | (1064) | | | |
| | | | SPZ | 11.8 | PP | 4 | 14.0 | 1.2 | 1107 | | | |
| | | | SPZ | 11.8 | e | 5 | 24.5 | 1.4 | 1066 | | | |
| | | | LPN | 1.40 | S | 7 | 17 | 17.0 | 272 | | | |
| | | | LPT | 2.14 | S | 7 | 17 | 13.0 | 326 | | | |
| | | | SPR | 11.8 | Lg | | | 1.6 | [illegible] | | | |

| | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] | | | | |
| | | | SPN | 4.0 | Lg | | | 1.9 | 2000 | | | | |
| | | | SPE | 4.0 | Lg | | | 1.6 | 1700 | | | | |
| | | | LPN | 1.04 | LQ | | | (15.0) | (2020) | | | | |
| | | | LPZ | 0.10 | LR | | | 14.9 | 5547 | | | | 3,790.00 |
| KC-MO | Kansas City, Missouri | 1917 | SPZ | 11.0 | P | 4 | 71.4 | 1.1 | 956 | 5.06 | | | |
| | | | SPZ | 11.0 | e | 4 | 65.3 | (1.1) | (1060) | | | | |
| | | | SPZ | 11.0 | PP | 4 | 10.0 | 1.2 | 1107 | | | | |
| | | | SPZ | 11.0 | e | 5 | 24.5 | 1.4 | 1066 | | | | |
| | | | LPN | 3.40 | S | 7 | 17 | 12.5 | 270 | | | | |
| | | | LPZ | 2.14 | S | 7 | 17 | 12.8 | 324 | | | | |
| | | | SPN | 12.7 | Lg | | | 1.4 | 900 | | | | |
| | | | SPZ | 10.1 | Lg | | | 1.8 | 1839 | | | | |
| | | | LPN | 0.9 | LQ | | | 15.0 | 5017 | | | | |
| | | | LPZ | 0.729* | LQ | | | 15.0 | 4330 | | | | |
| | | | LPZ | 0.220 | LR | | | 11.0 | 7934 | | | | 3,664.91 |
| PG-BC | Prince George, British Columbia, Canada | 1915 | SPZ | 13.0 | P | 6 | 70.5 | 1.4 | 694 | 5.65 | | | |
| | | | SPZ | 13.0 | e | 6 | 66.0 | 1.4 | 3676 | | | | |
| | | | SPZ | 13.0 | PP | 6 | 10.0 | 1.2 | 540 | | | | |
| | | | SPZ | 13.0 | e | 6 | 18.9 | 1.5 | 1273 | | | | |
| | | | LPN | 3.45 | S | 7 | 22 | (21.0) | (1111) | | | | |
| | | | LPZ | 1.56 | S | | | (23.0) | (81.3) | | | | |
| | | | SPN | 11.5 | Lg | | | 2.2 | 1154 | | | | |
| | | | SPZ | 13.8 | Lg | | | 2.2 | 790 | | | | |
| | | | LPN | 2.45 | LQ | | | 13.0 | 3711 | | | | |
| | | | LPZ | 1.04 | LQ | | | 11.0 | 6216 | | | | |
| | | | LPZ | 0.5 | LR | | | 11.0 | 3111 | | | | 2,600.00 |
| JE-LA | Jena, Louisiana | 2314 | SPZ | 12.0 | P | 4 | (40.7) | 1.0 | 3050 | 4.95 | | | |
| | | | SPZ | 12.0 | e | 6 | 55.1 | 1.0 | 2147 | | | | |
| | | | SPZ | 12.0 | PP | 5 | 65.0 | 1.3 | 792 | | | | |
| | | | LPN | 1.03 | S | 8 | 30 | 13.0 | 1005 | | | | |
| | | | LPZ | 1.33 | S | 8 | 30 | 13.0 | 800 | | | | |
| | | | SPN | 13.42 | Lg | | | 1.8 | 7543 | | | | |
| | | | SPZ | 13.42 | Lg | | | 1.8 | 3972 | | | | |
| | | | LPN | 1.03 | LQ | | | 13.0 | 2140 | | | | |
| | | | LPZ | | LQ | | | --- | --- | | | | |
| | | | LPZ | 0.30 | LR | | | 12.0 | 17000 | | | | 8,121.00 |
| RK-ON | Red Lake, Ontario Canada | 2366 | SPZ | 12.0 | P | 6 | 65.4 | (1.2) | (1960) | 16.40 | | | |
| | | | SPZ | 12.0 | e | 6 | 40.4 | 1.6 | 4106 | | | | |
| | | | SPZ | 12.0 | e | 4 | 55.7 | 1.5 | 1763 | | | | |
| | | | LPZ | 5.95 | S | 8 | 63 | (20.0) | (60.0) | | | | |
| | | | SPZ | 11.9 | Lg | | | 1.8 | 757 | | | | |
| | | | LPZ | 3.95 | LQ | | | 16.0 | 777 | | | | |
| | | | LPZ | 0.584 | LR | | | 13.0 | 2197 | | | | 1,369.06 |
| [illegible] | [illegible], Alabama | 2439 | SPZ | 50.3 | P | 5 | 16.0 | (1.6) | (163) | (5.52) | | | |
| | | | SPZ | 50.3 | e | 5 | 30.1 | (1.5) | (249) | | | | |
| | | | SPZ | 50.3 | e | 5 | 42.4 | 1.2 | 192 | | | | |
| | | | SPZ | 50.3 | PP | 5 | 60.6 | 1.3 | 102 | | | | |
| | | | LPN | 3.7 | S | 9 | 36 | 12.0 | 433 | | | | |
| | | | LPZ | 6.06 | S | 9 | 36 | 17 | 320 | | | | |
| | | | SPN | 50.2 | Lg | | | 2.6 | 573 | | | | |
| | | | SPZ | 41.7 | Lg | | | (2.2) | (1437) | | | | |
| | | | LPN | 3.3 | LQ | | | 18 | 1969 | | | | |
| | | | LPZ | 6.06 | LQ | | | 18 | 871 | | | | |
| | | | LPZ | 0.495 | LR | | | 17 | 1642 | | | | 3,424.34 |
| CPO | Cumberland Plateau Observatory, Tennessee | 2794 | SPZ-E | 35.0 | P | 5 | 24.3 | 0.9 | 442 | 6.11 | | | |
| | | | LPN | 5.5 | S | 9 | 40 | (20.0) | (87.5) | | | | |
| | | | LPE | 5.0 | S | | | 18.0 | 150 | | | | |
| | | | SPN | 25.3 | Lg | | | 2.0 | 1111 | | | | |
| | | | SPE | 35.0 | Lg | | | 1.7 | 404 | | | | |
| | | | LPZ | 0.25 | LQ | | | 14.0 | 9438 | | | | |



2

Principal Phases
GREELEY
20 December 1966
15:30:00.12

| Code | Station | Distance (km) | Inst. | Magni-fication (k) Film x 10 | Phase | Observed Travel Time (min) | (sec) | Period T (sec) | Maximum Amplitude A/T | Magni-tude mb | me | Area (mm²) LR |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | LPE | 0.25 | LQ | | | 14.0 | 1645 | | | |
| | | | LPZ | 0.25 | LR | | | 14.0 | 5863 | | | 4,560.00 |
| AX2AL | Alexander City, Alabama | 2796 | SPZ | 12.5 | P | 5 | 28.0 | 1.2 | 1045 | 6.51 | | |
| | | | SPZ | 12.5 | e | 5 | 30.2 | (1.3) | (1521) | | | |
| | | | SPZ | 12.5 | e | 5 | 38.1 | 1.2 | 688 | | | |
| | | | LPR | 6.14 | S | 9 | 55 | 16 | 236 | | | |
| | | | LPT | 3.04 | S | 9 | 55 | 17 | 152 | | | |
| | | | SPR | 12.8 | Lg | | | 2.0 | 444 | | | |
| | | | SPT | 12.7 | Lg | | | (2.4) | (974) | | | |
| | | | LPR | 6.14 | LQ | | | 23 | 599 | | | |
| | | | LPT | 3.04 | LQ | | | 21 | 1137 | | | |
| | | | LPZ | 0.234 | LR | | | (16) | (2472) | | | 5,491.45 |
| WH2YK | Whitehorse, Yukon Territory, Canada | 2913 | SPZ | 16.7 | P | 5 | 36.7 | 1.0 | 135 | 5.55 | | |
| | | | SPZ | 16.7 | e | 5 | 38.7 | 0.9 | (126) | | | |
| | | | SPT | 17.1 | Lg | | | 2.6 | 657 | | | |
| | | | LPT | 1.08 | LQ | | | 18 | 2348 | | | |
| | | | LPZ | 1.41 | LR | | | 13 | 4348 | | | 5,223.40 |
| AE-NC | Albemarle, North Carolina | 3249 | SPZ | 21.5 | P | 6 | 03.2 | 1.3 | 552 | 6.34 | | |
| | | | SPR | 21.0 | e | 6 | 19.3 | 1.3 | 253 | | | |
| | | | SPZ | 21.5 | e | 6 | 48.2 | 1.2 | 197 | | | |
| | | | SPT | 17.0 | Lg | | | 2.4 | 1651 | | | |
| | | | LPT | 1.32* | LQ | | | 13 | 1664 | | | |
| | | | LPZ | 1.24* | LR | | | 16 | 1974 | | | 1,951.61 |
| BE-FL | Belleview, Florida | 3318 | SPZ | 23.1 | P | 6 | (09.9) | 1.3 | 651 | 6.41 | | |
| | | | SPZ | 23.1 | e | 6 | 16.2 | 1.0 | 162 | | | |
| | | | SPZ | 23.1 | e | 6 | 26.3 | 1.2 | 223 | | | |
| | | | SPZ | 23.1 | e | 6 | 42.4 | 1.6 | 303 | | | |
| | | | SPZ | 23.1 | e | 7 | 03.5 | 1.2 | 238 | | | |
| | | | SPZ | 23.1 | (PCP) | 9 | 28.1 | 1.1 | 216 | | | |
| | | | LPR | 1.53 | S | 11 | 15 | 20 | 108 | | | |
| | | | LPT | 1.0 | S | 11 | 15 | 20 | 102 | | | |
| | | | SPR | 21.4 | Lg | | | 1.8 | 387 | | | |
| | | | SPT | 20.8 | Lg | | | 1.8 | 277 | | | |
| | | | LPR | 1.53 | LQ | | | 17 | 1088 | | | |
| | | | LPT | 1.0 | LQ | | | (17) | (241) | | | |
| | | | LPZ | 1.83 | LR | | | 17 | 1961 | | | 4,642.08 |
| LS-NH | Lisbon, New Hampshire | 3788 | SPZ | 25 | P | 6 | 46.2 | 1.0 | 535 | 6.43 | | |
| | | | SPZ | 25.0 | e | 6 | 48.2 | 1.0 | 530 | | | |
| | | | SPR | 28.5 | e | 6 | 56.2 | 1.0 | 167 | | | |
| | | | SPZ | 25.0 | e | 7 | 09.4 | 1.4 | 357 | | | |
| | | | SPT | 35.5 | Lg | | | 1.8 | 592 | | | |
| | | | LPT | 0.36 | LQ | | | 16 | 2225 | | | |
| | | | LPZ | 0.33 | LR | | | 10 | 6774 | | | 2,015.15 |
| HN-ME | Houlton, Maine | 4082 | SPZ | 17.7 | P | 7 | 08.9 | 1.1 | 770 | 6.42 | | |
| | | | SPZ | 17.7 | e | 7 | 15.9 | 1.2 | 486 | | | |
| | | | SPZ | 17.7 | PCP | 9 | 31.2 | 1.0 | 70.6 | | | |
| | | | SPT | 16.5 | Lg | | | 2.5 | 589 | | | |
| | | | LPT | 1.93 | LQ | | | 16.0 | 2064 | | | |
| | | | LPZ | 2.19 | LR | | | 14.0 | 898 | | | 1,178.08 |

| | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LS-NH | Lisbon, New Hampshire | 3788 | SPZ | 25 | P | 6 | 46.2 | 1.0 | 535 | 6.43 | | |
| | | | SPZ | 25.0 | a | 6 | 48.2 | 1.0 | 530 | | | |
| | | | SPR | 28.5 | e | 6 | 56.2 | 1.0 | 167 | | | |
| | | | SPZ | 25.0 | a | 7 | 09.4 | 1.4 | 357 | | | |
| | | | SPT | 35.5 | Lg | | | 1.8 | 592 | | | |
| | | | LPT | 0.36 | LQ | | | 16 | 2225 | | | |
| | | | LPZ | 0.33 | LR | | | 10 | 6774 | | | 2,015.15 |
| HN-ME | Houlton, Maine | 4082 | SPZ | 17.7 | P | 7 | 08.9 | 1.1 | 770 | 6.42 | | |
| | | | SPZ | 17.7 | e | 7 | 15.9 | 1.2 | 486 | | | |
| | | | SPZ | 17.7 | PCP | 9 | 31.2 | 1.0 | 70.6 | | | |
| | | | SPT | 16.5 | Lg | | | 2.5 | 589 | | | |
| | | | LPT | 1.93 | LQ | | | 16.0 | 2064 | | | |
| | | | LPZ | 2.19 | LR | | | 14.0 | 898 | | | 1,178.08 |
| SV3QB | Schaffarvilla, Quebec Canada | 4195 | SPZ | 15.6 | P | 7 | 16.3 | (1.3) | (508) | (6.21) | | |
| | | | SPZ | 15.6 | e | 7 | 18.6 | 1.1 | 301 | | | |
| | | | SPZ | | PP | 8 | 45.2 | 1.2 | 397 | | | |
| | | | SPR | 16.5 | Lg | | | 1.8 | 218 | | | |
| | | | SPT | 16.4 | Lg | | | 1.8 | 176 | | | |
| | | | LPR | 7.65 | LQ | | | 18.0 | 146 | | | |
| | | | LPT | 7.4 | LQ | | | 17.0 | 145 | | | |
| | | | LPZ | 4.75 | (LR) | | | 13 | 838 | | | 2,936.84 |
| NP-NT | Mould Bay, Northwest Territories, Canada | 4344 | SPZ | | P | 7 | 29.1 | --- | --- | | | |
| | | | SPZ | 76.6* | e | 7 | 42.9 | 1.0 | 176 | | | |
| | | | SPZ | 236 | a | 8 | 35.1 | 1.3 | 92.6 | | | |
| | | | SPZ | | (PP) | 8 | 57.0 | --- | --- | | | |
| | | | SPZ | 76.6* | (PPP) | 9 | 19.7 | 1.8 | 261 | | | |
| | | | SPZ | 76.6* | (PCP) | 9 | 39.7 | 1.0 | 97.9 | | | |
| | | | SPT | 121* | Lg | | | 2.6 | 793 | | | |
| | | | LPT | | LQ | | | --- | --- | | | |
| | | | LPZ | 0.88 | LR | | | 13 | 780 | | | |
| FH-PM | Fort Sharman, Panama | 4789 | LPT | 1.55 | LQ | | | 22 | 138 | | | |
| | | | LPZ | 1.55 | LR | | | 21 | 217 | | | 1,248.39 |
| TE-GL | Thula, Greenland | 4956 | SPZ | 71 | P | 8 | 12.8 | 1.4 | 152 | 5.79 | | |
| | | | SPZ | 71 | (PCP) | 8 | 55.2 | 0.8 | 24.0 | | | |
| | | | SPZ | 71 | (PP) | 9 | 55.9 | (1.7) | (231) | | | |
| | | | SPT | 67 | Lg | | | 2.8 | 262 | | | |
| | | | LPT | 1.48 | LQ | | | 17 | 925 | | | |
| | | | LPZ | 1.72 | LR | | | 13 | 747 | | | 1,416.91 |
| OO-NW | Oslo, Norway | 8120 | SPZ | 58.5 | P | 11 | 30.6 | 0.9 | 88.1 | 5.84 | | |
| | | | SPZ | 58.5 | a | 11 | 32.1 | 0.9 | 86.3 | | | |
| | | | SPZ | 58.5 | e | 11 | 36.3 | 0.8 | 34.6 | | | |
| | | | SPZ | 58.5 | PCP | 11 | 47.9 | 1.0 | 55.6 | | | |
| | | | SPZ | 58.5 | e | 14 | 57.9 | 1.8 | 92.3 | | | |
| | | | LPZ | 13.2 | [illegible] | | | 23 | 55.4 | | | |
| | | | LPZ | 13.2 | LR | | | 19 | 129 | | | 461.36 |
| GG-GR | Grafenberg, Germany | 9095 | SPZ | ** | P | 12 | 21.1 | | | | | |
| | | | LPZ | ** | LR | | | | | | | |

A/T mu/sec
() Doubtful Values or Phases
* Measurements Made from Playouts
--- Maximum Amplitudes Clipped on Film and Tape
** Magnification not available

Principal Phases - GREELEY

Table 2 Page 2

2

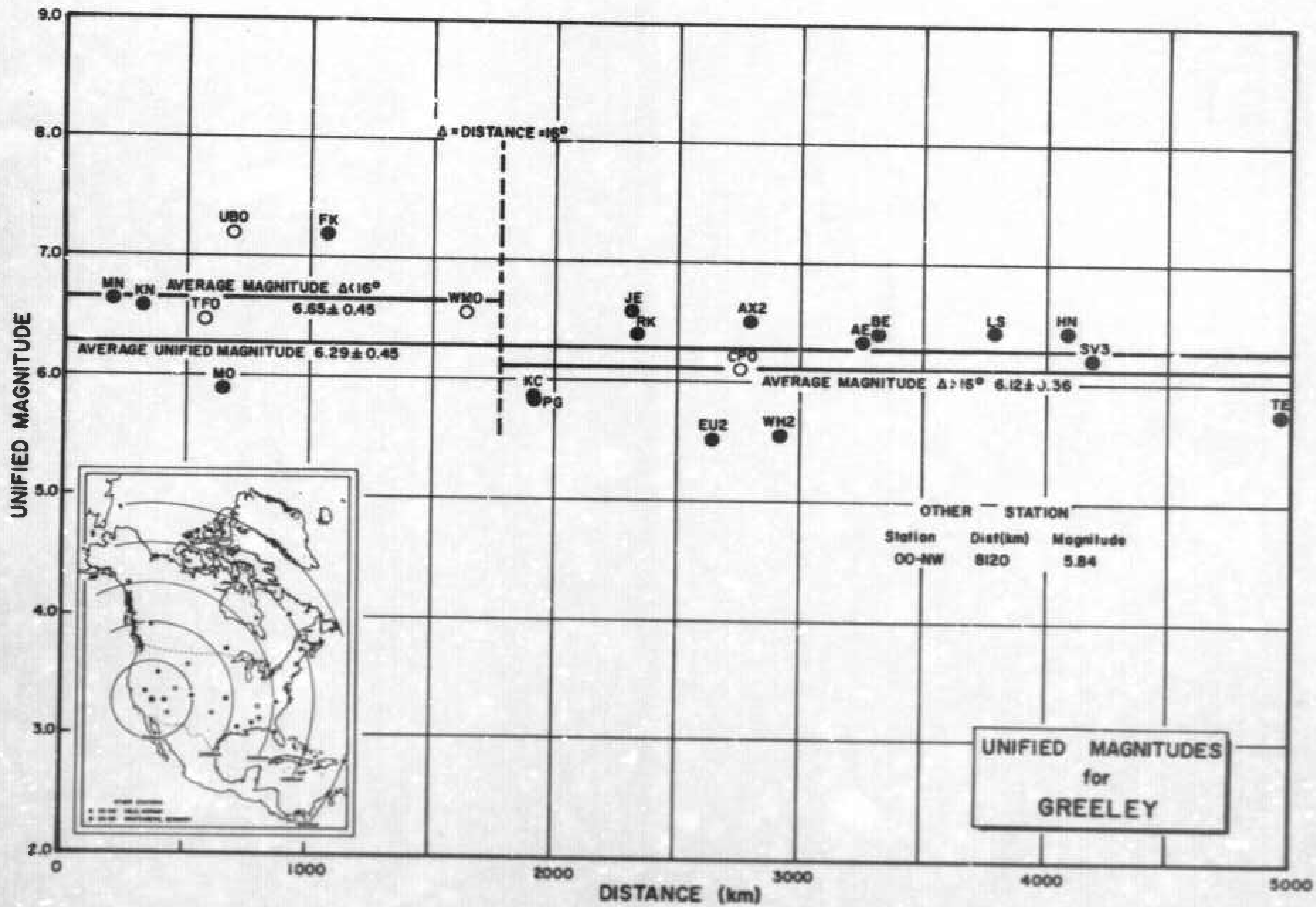
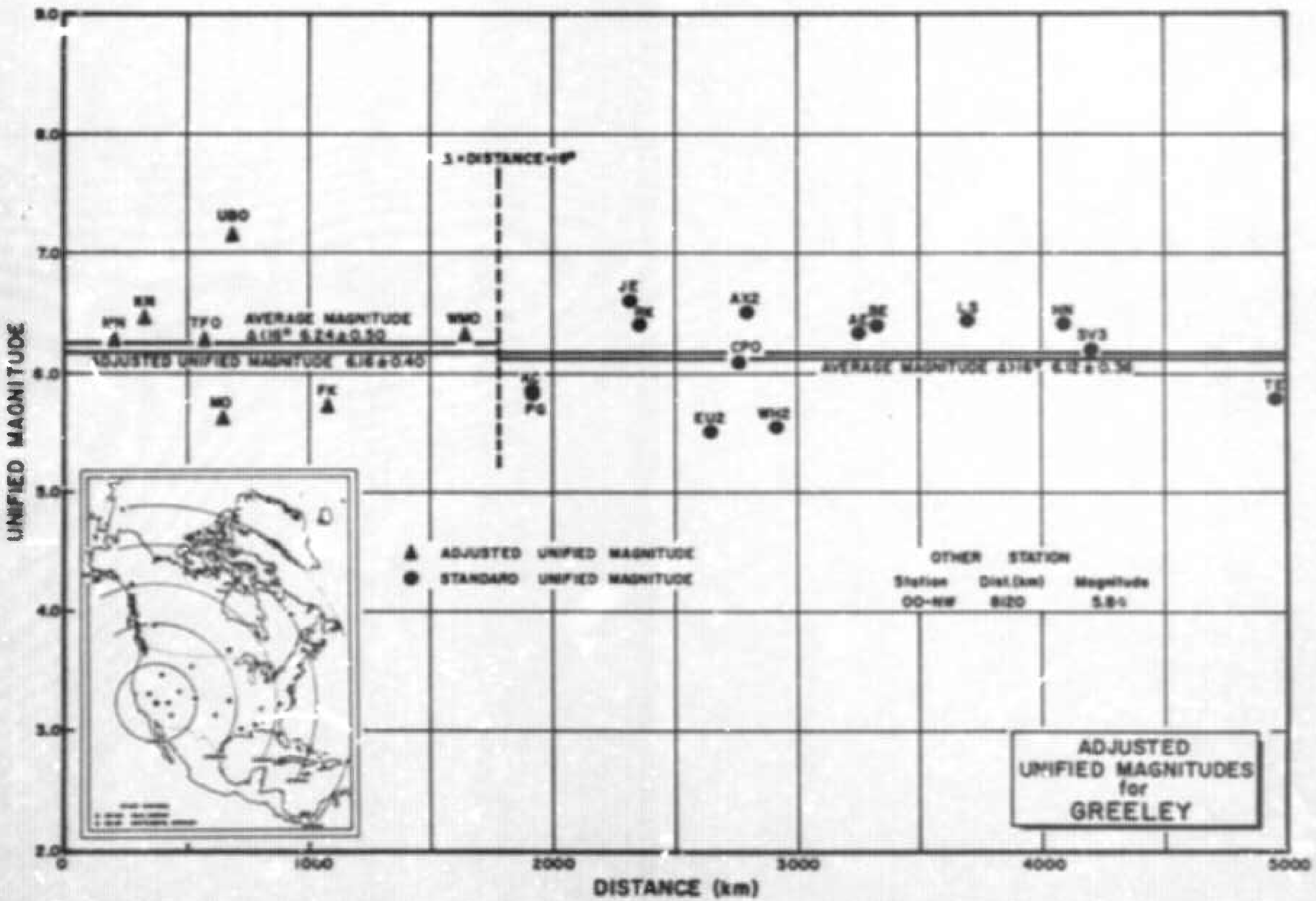
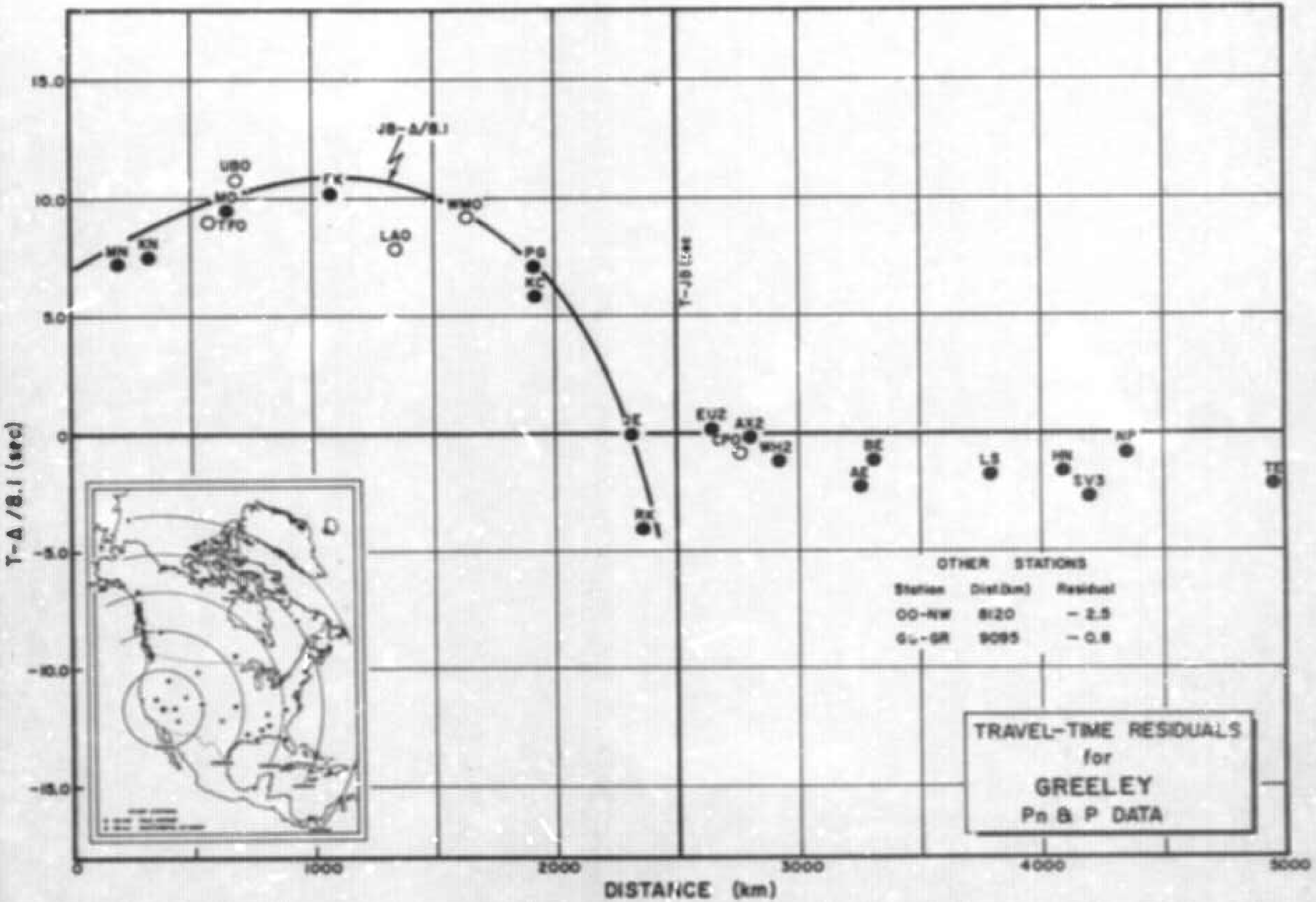

UNIFIED MAGNITUDE
DISTANCE (km)
Δ = DISTANCE = 16°
AVERAGE MAGNITUDE Δ<16°
6.65 ± 0.45
AVERAGE UNIFIED MAGNITUDE 6.29 ± 0.45
AVERAGE MAGNITUDE Δ>16° 6.12 ± 0.36
UBO
FK
MN
KN
TFO
WMO
MO
KC
PG
JE
RK
AX2
CPO
EU2
WH2
AE
BE
LS
HN
SV3
TE
OTHER STATION
Station Dist(km) Magnitude
OO-NW 8120 5.84
UNIFIED MAGNITUDES
for
GREELEY

Figure 2



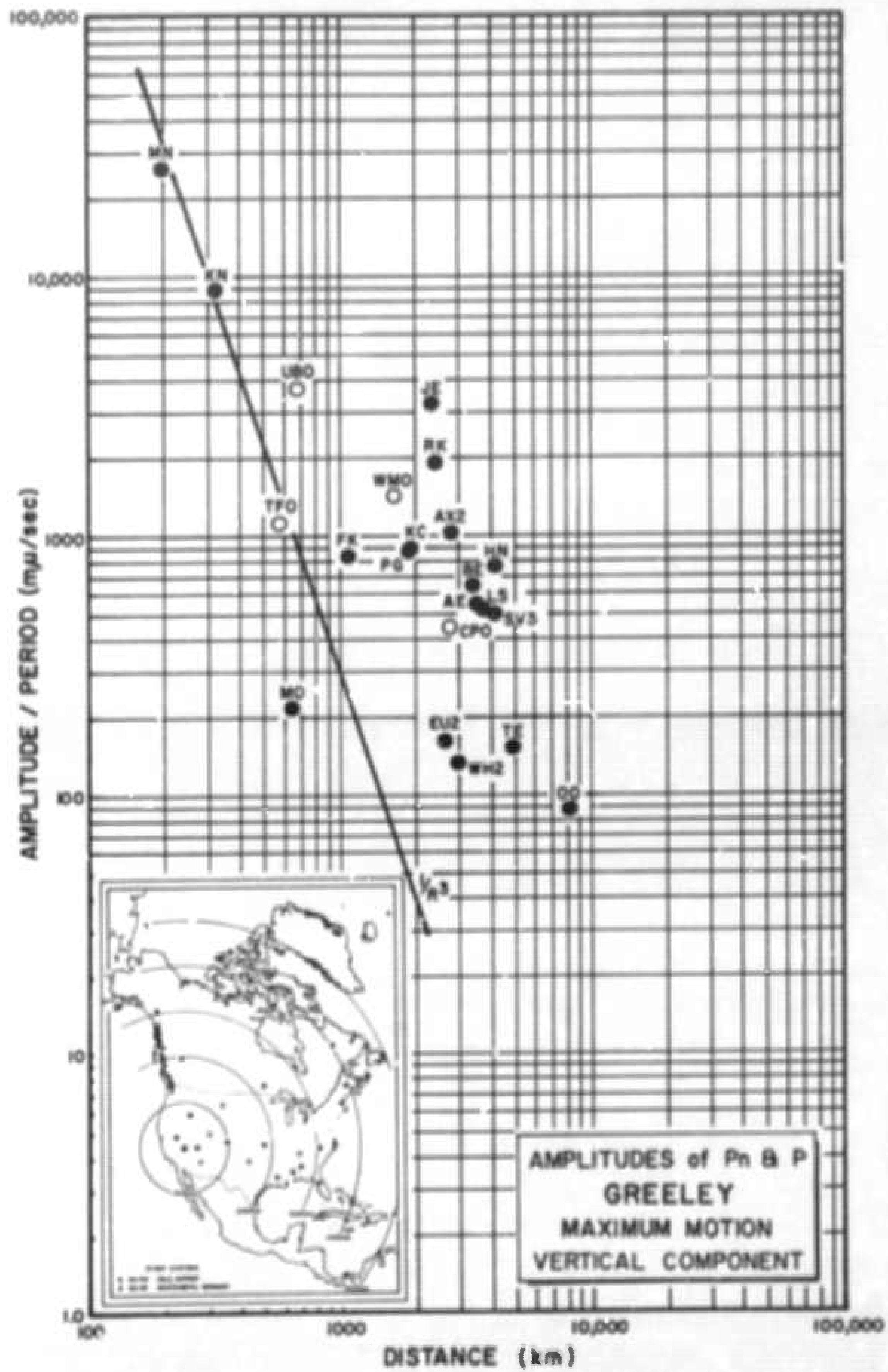
UNIFIED MAGNITUDE
DISTANCE (km)
AVERAGE MAGNITUDE
ADJUSTED UNIFIED MAGNITUDE
AVERAGE MAGNITUDE
ADJUSTED UNIFIED MAGNITUDE
STANDARD UNIFIED MAGNITUDE
OTHER STATION
Station Dist.(km) Magnitude
OO-NW 8120
ADJUSTED UNIFIED MAGNITUDES for GREELEY


Figure 3



TRAVEL-TIME RESIDUALS
for
GREELEY
Pn & P DATA
OTHER STATIONS
Station Dist(km) Residual
OO-NW 8120 − 2.5
GL-GR 9095 − 0.8
T − Δ / 8.1 (sec)
DISTANCE (km)
JB − Δ/8.1
T − JB
MN
KN
UBO
MO
TFO
FK
LAO
WMO
PG
KC
DE
RK
EUZ
CPO
AXZ
WHZ
BE
AE
LS
HN
SV3
NP
TE


Figure 4



AMPLITUDES of Pn & P
GREELEY
MAXIMUM MOTION
VERTICAL COMPONENT
AMPLITUDE / PERIOD (mμ/sec)
DISTANCE (km)
100,000
10,000
1000
100
10
1.0
100
1000
10,000
100,000
MN
KN
UBO
TFO
MO
WMO
FK
PG
KC
JE
RK
AX2
HN
AE
LS
EV3
CPO
EU2
WH2
TE
OO
1/R³


Figure 5

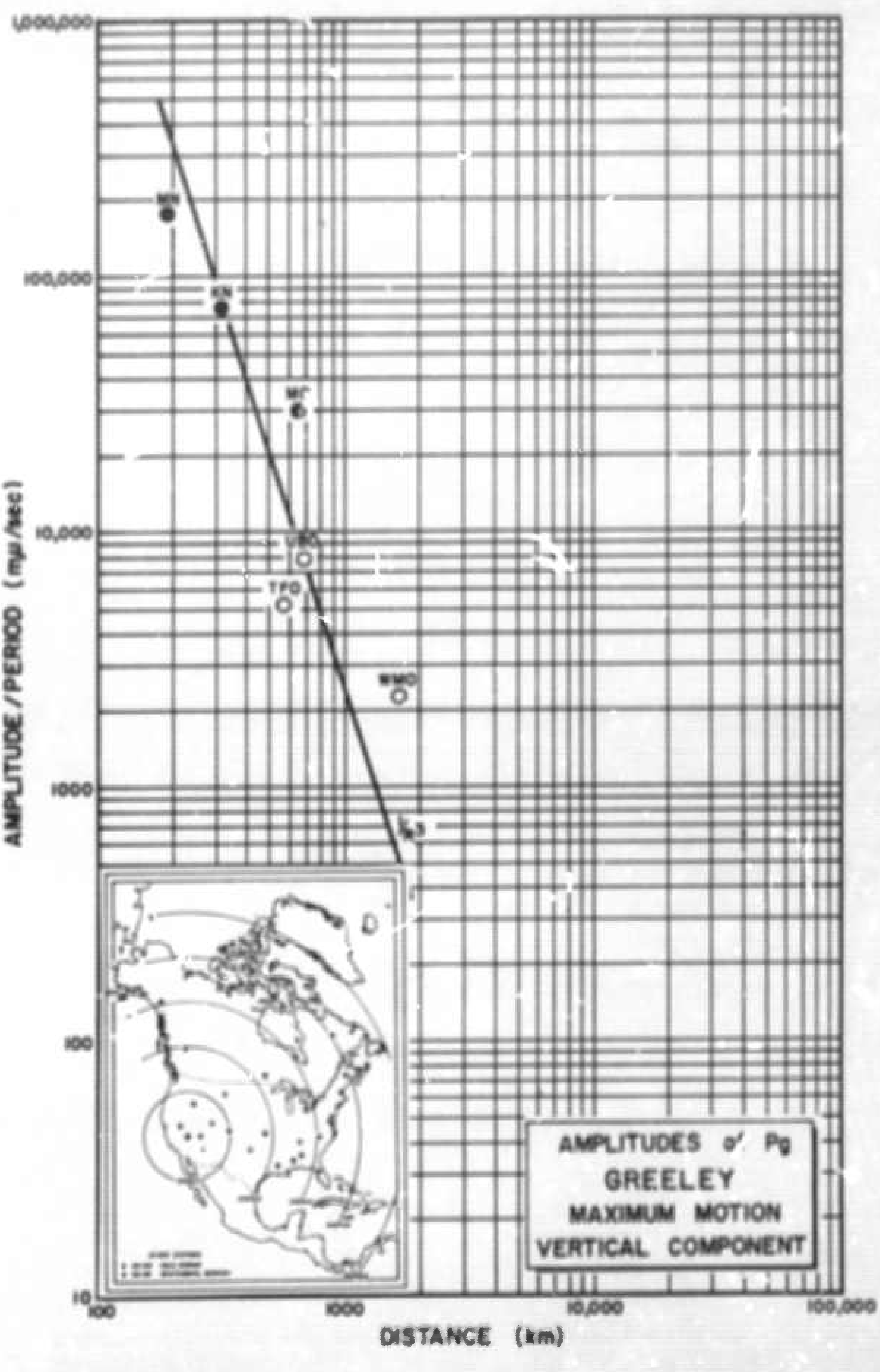

1,000,000
100,000
10,000
1000
100
10
100
1000
10,000
100,000
AMPLITUDE / PERIOD (mμ/sec)
DISTANCE (km)
TFO
WMO
AMPLITUDES of Pg
GREELEY
MAXIMUM MOTION
VERTICAL COMPONENT

Figure 6

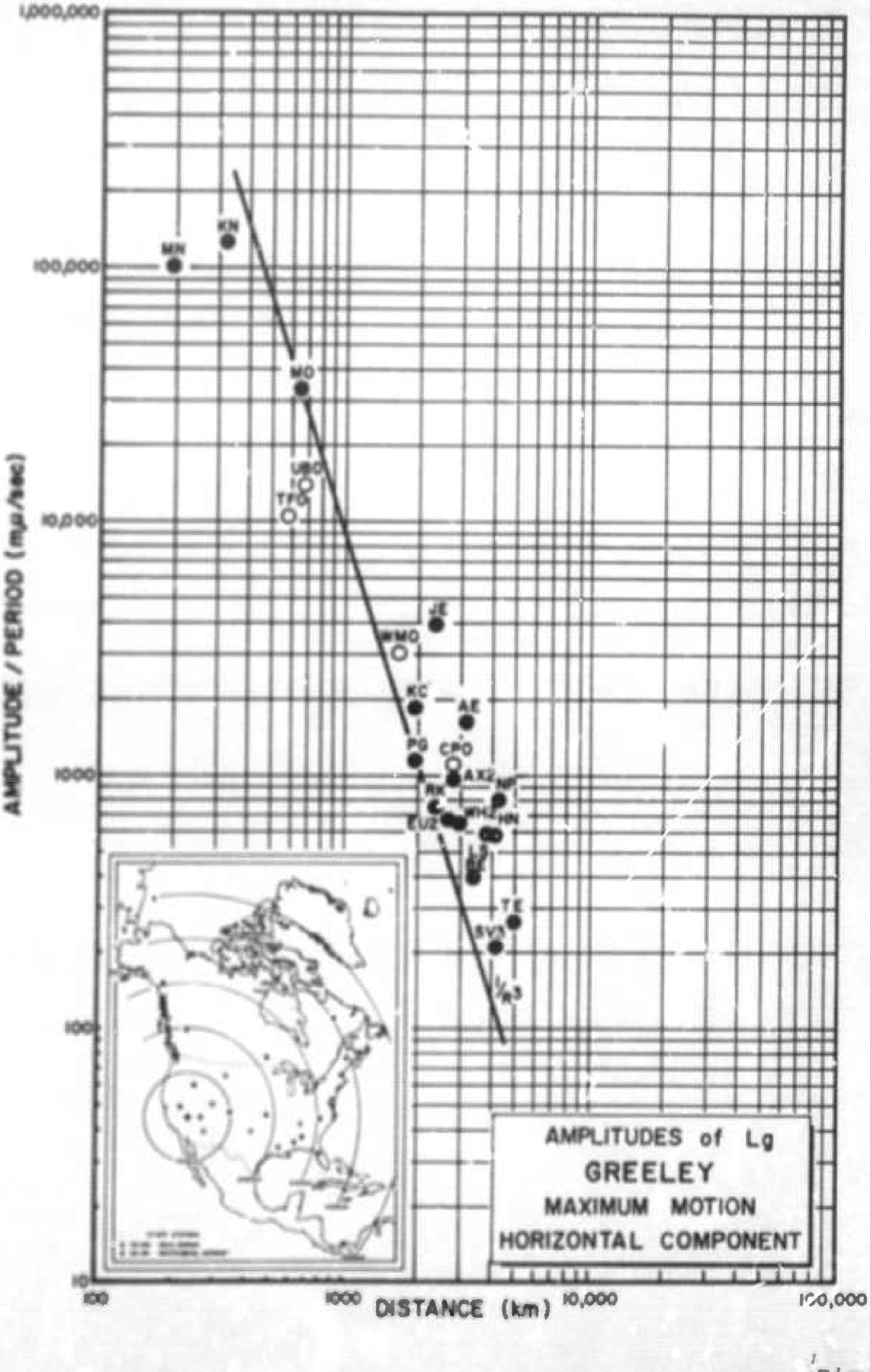

AMPLITUDES of Lg
GREELEY
MAXIMUM MOTION
HORIZONTAL COMPONENT
AMPLITUDE / PERIOD (mμ/sec)
DISTANCE (km)
1,000,000
100,000
10,000
1000
100
10
100
1000
10,000
100,000
MN
KN
MO
UBO
TFO
JE
WMO
KC
AE
PG
CPO
AX2
NP
RK
EUZ
WH2
HN
TE
SV3
1/R3

Figure 7

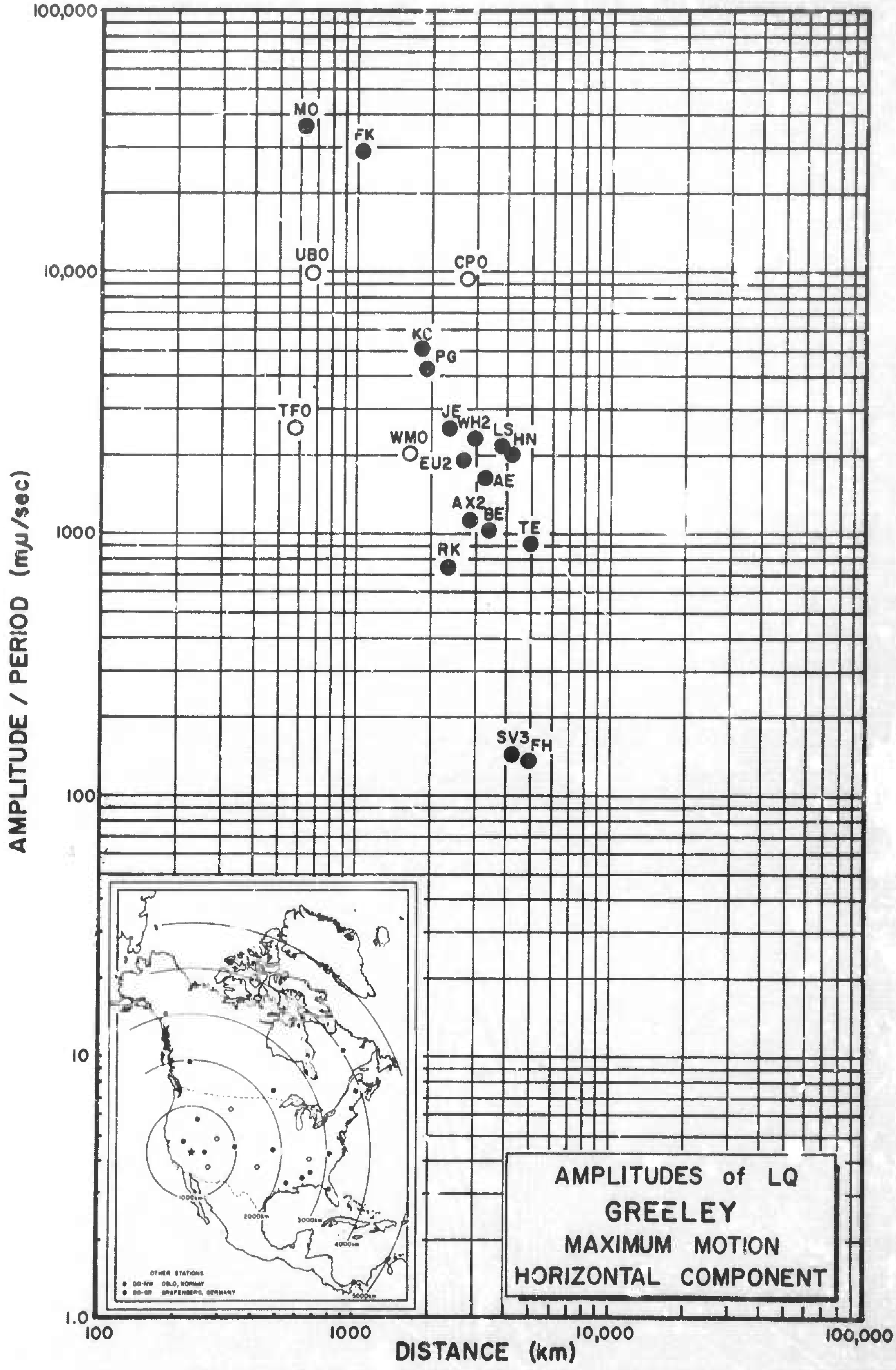

AMPLITUDE / PERIOD (mμ/sec)
100,000
10,000
1000
100
10
1.0
100
1000
10,000
100,000
DISTANCE (km)
MO
FK
UBO
CPO
KC
PG
TFO
JE
WH2
LS
HN
WMO
EU2
AE
AX2
BE
TE
RK
SV3
FH
AMPLITUDES of LQ
GREELEY
MAXIMUM MOTION
HORIZONTAL COMPONENT

Figure 8

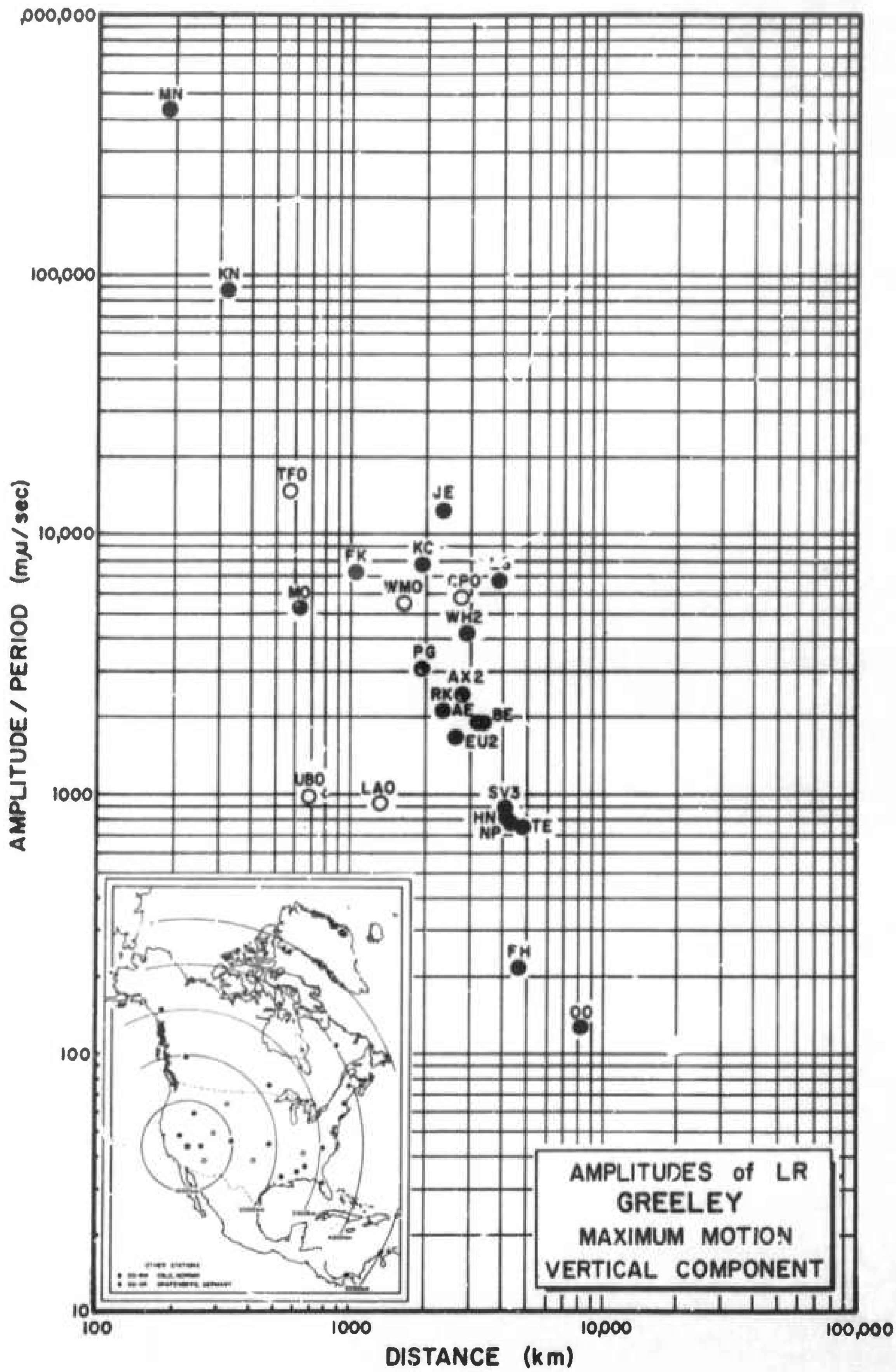

AMPLITUDES of LR
GREELEY
MAXIMUM MOTION
VERTICAL COMPONENT
AMPLITUDE / PERIOD (mμ/sec)
DISTANCE (km)
,000,000
100,000
10,000
1000
100
10
100
1000
10,000
100,000
MN
KN
TFO
JE
FK
KC
MO
WMO
CPO
WH2
PG
AX2
RK
AE
BE
EU2
UBO
LAO
SV3
HN
NP
TE
FH
OO

Figure 9

| Code | Station | Distance (km) | Geographic Latitude | Geographic Longitude | Elev. (km) | Computed Azimuth | | Installed Azimuth | | Large or Small SP | LP Inst. |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | Epi. Sta. | Sta. Epi. | Radial | Tang. | | |
| MN-NV* | Mina, Nevada | 198 | 38°26'10"N | 118°08'53"W | 1.52 | 310° | 129° | 308° | 038° | L | X |
| KN-UT* | Kanab, Utah | 320 | 37°01'22"N | 112°49'39"W | 1.74 | 94° | 277° | 95° | 185° | L | X |
| TFSO-260 | Tonto Forest Observatory, Arizona | 572 | 34°17'13"N | 111°16'03"W | 1.49 | 134° | 307° | 90° | 0° | JM | X |
| MO-ID* | Mountain Home, Idaho | 541 | 43°04'19"N | 116°15'56"W | .79 | 01° | 181° | 359° | 89° | L | X |
| UBSO-210 | Uinta Basin Observatory, Utah | 683 | 40°19'18"N | 109°34'07"W | 1.60 | 58° | 243° | 90° | 0° | JM | X |
| FK-CO* | Franktown, Colorado | 1073 | 39°35'12"N | 104°27'42"W | 1.80 | 73° | 260° | 79° | 169° | L | X |
| LAO | Subarray AO-10, Montana | 1340 | 46°41'19"N | 106°13'30"W | .90 | 36° | 223° | | | HSZ | X |
| WMSO-26 | Wichita Mountain Observatory, Oklahoma | 1629 | 34°43'05"N | 98°35'21"W | .51 | 95° | 285° | 90° | 0° | JM | X |
| KC-MO | Kansas City, Missouri | 1910 | 39°21'31"N | 94°40'17"W | .27 | 76° | 270° | 133° | 233° | S | X |
| PG-BC | Prince George, British Columbia, Canada | 1915 | 53°59'50"N | 122°31'23"W | .91 | 348° | 163° | 110° | 200° | L | X |
| JE-LA | Jena, Louisiana | 2314 | 31°47'05"N | 92°00'55"W | .05 | 98° | 292° | 286° | 016° | L | X |
| RK-ON* | Red Lake Ontario, Canada | 2346 | 50°50'30"N | 93°40'20"W | .37 | 43° | 239° | 58° | 148° | S | X |
| EU2AL | Eutaw, Alabama | 2639 | 32°47'47"N | 87°53'05"W | .04 | 92° | 289° | 41° | 131° | S | X |
| CPSO-28 | Cumberland Plateau Observatory, Tennessee | 2759 | 35°35'41"N | 85°34'13"W | .57 | 85° | 283° | 90° | 0° | JM | X |
| AX2AL | Alexander City, Alabama | 2796 | 32°46'38"N | 86°07'48"W | .31 | 91° | 289° | 138° | 228° | L | X |
| WH2YK* | Whitehorse, Yukon Territories, Canada | 2913 | 60°41'41"N | 134°58'02"W | .85 | 339° | 145° | 325° | 055° | L | X |
| AE-NC* | Albemarle, North Carolina | 3349 | 35°26'01"N | 80°03'52"W | .18 | 83° | 284° | 104° | 194° | Geotech | X |
| BF-FL | Belleview, Florida | 3318 | 28°54'19"N | 83°03'52"W | .72 | 96° | 295° | 140° | 230° | S | X |
| LS-NH* | Lisbon, New Hampshire | 3788 | 44°14'18"N | 71°55'21"W | .29 | 64° | 274° | 94° | 184° | Geotech | X |
| HN-ME* | Houlton, Maine | 4082 | 46°09'43"N | 67°59'09"W | .21 | 60° | 274° | 93° | 183° | S | X |
| SV3QB | Schefferville, Quebec, Canada | 4195 | 54°48'39"N | 66°45'00"W | .50 | 46° | 263° | 139° | 229° | S | X |
| MB-NT* | Mould Bay, Northwest Territories, Canada | 4344 | 76°15'00"N | 119°22'18"W | .06 | 359° | 176° | 356° | 86° | JMZ S | X |
| FS-PM* | Fort Sherman, Panama | 4789 | 09°21'47"N | 79°57'30"W | .03 | 121° | 316° | | | Geotech | X |
| TE-GL* | Thule, Greenland | 4956 | 76°29'50"N | 68°36'20"W | .21 | 14° | 237° | 57° | 147° | Geotech | X |
| OO-NW* | Oslo, Norway | 8120 | 61°02'53"N | 10°53'42"E | .56 | 34° | 318° | 138° | 228° | L | X |
| GG-GR* | Grafenberg, Germany | 9095 | 49°41'32"N | 11°13'55"E | .53 | 31° | 320° | 140° | 230° | L | X |

* Seismometers Orientated Toward Nevada Test Site

Recording Site Information - Greeley

Appendix 1 (A)

Unified Magnitude: $m = \log_{10}(A/T), + B$

where $A$ = zero to peak ground motion in millimicrons

$= \frac{(mm)\ (1000)}{K}$

$T$ = signal period in seconds

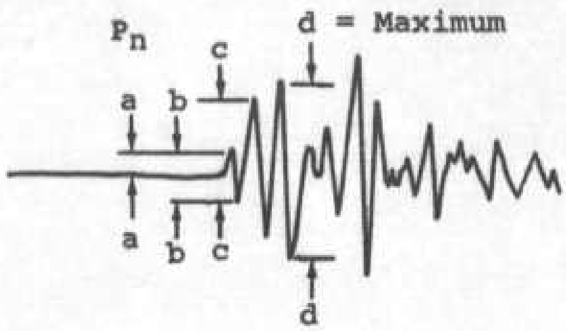
$B$ = distance factor (see Table below)

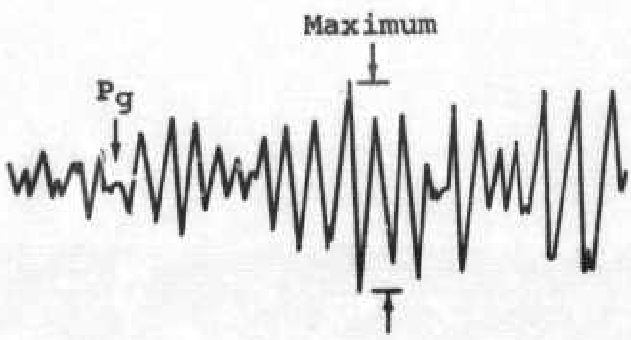
$mm$ = record amplitude in millimeters zero to peak

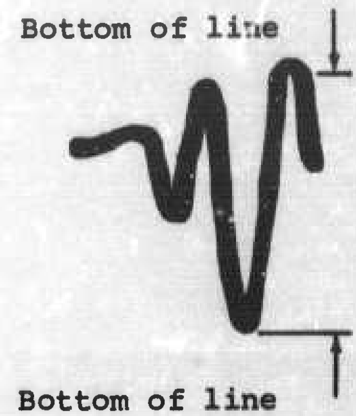
$K$ = magnification in thousands at signal frequency

**Table of Distance Factors (B) for Zero Depth**

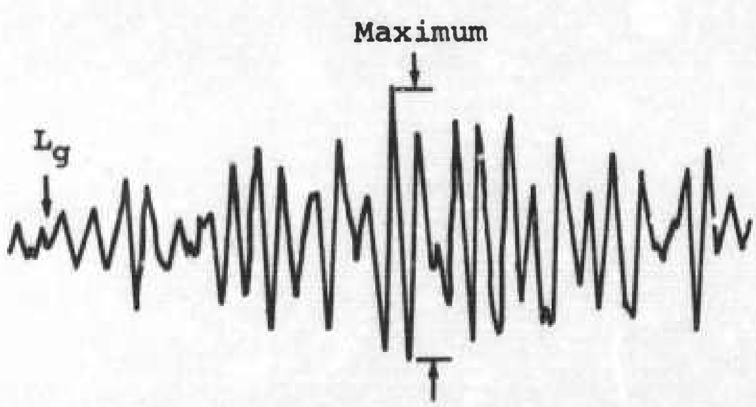
| Dist (deg) | B | Dist (deg) | B | Dist (deg) | B | Dist (deg) | B |
|---|---|---|---|---|---|---|---|
| 0° | - | 27° | 3.5 | 54° | 3.8 | 80° | 3.7 |
| 1 | - | 28 | 3.6 | 55 | 3.8 | 81 | 3.8 |
| 2 | 2.2 | 29 | 3.6 | 56 | 3.8 | 82 | 3.9 |
| 3 | 2.7 | 30 | 3.6 | 57 | 3.8 | 83 | 4.0 |
| 4 | 3.1 | 31 | 3.7 | 58 | 3.8 | 84 | 4.0 |
| 5 | 3.4 | 32 | 3.7 | 59 | 3.8 | 85 | 4.0 |
| 6 | 3.6 | 33 | 3.7 | 60 | 3.8 | 86 | 3.9 |
| 7 | 3.8 | 34 | 3.7 | 61 | 3.9 | 87 | 4.0 |
| 8 | 4.0 | 35 | 3.7 | 62 | 4.0 | 88 | 4.1 |
| 9 | 4.2 | 36 | 3.6 | 63 | 3.9 | 89 | 4.0 |
| 10 | 4.3 | 37 | 3.5 | 64 | 4.0 | 90 | 4.0 |
| 11 | 4.2 | 38 | 3.5 | 65 | 4.0 | 91 | 4.1 |
| 12 | 4.1 | 39 | 3.4 | 66 | 4.0 | 92 | 4.1 |
| 13 | 4.0 | 40 | 3.4 | 67 | 4.0 | 93 | 4.2 |
| 14 | 3.6 | 41 | 3.5 | 68 | 4.0 | 94 | 4.1 |
| 15 | 3.3 | 42 | 3.5 | 69 | 4.0 | 95 | 4.2 |
| 16 | 2.9 | 43 | 3.5 | 70 | 3.9 | 96 | 4.3 |
| 17 | 2.9 | 44 | 3.5 | 71 | 3.9 | 97 | 4.4 |
| 18 | 2.9 | 45 | 3.7 | 72 | 3.9 | 98 | 4.5 |
| 19 | 3.0 | 46 | 3.8 | 73 | 3.9 | 99 | 4.5 |
| 20 | 3.0 | 47 | 3.9 | 74 | 3.8 | 100 | 4.4 |
| 21 | 3.1 | 48 | 3.9 | 75 | 3.8 | 101 | 4.3 |
| 22 | 3.2 | 49 | 3.8 | 76 | 3.9 | 102 | 4.4 |
| 23 | 3.3 | 50 | 3.7 | 77 | 3.9 | 103 | 4.5 |
| 24 | 3.3 | 51 | 3.7 | 78 | 3.9 | 104 | 4.6 |
| 25 | 3.5 | 52 | 3.7 | 79 | 3.8 | 105 | 4.7 |
| 26 | 3.4 | 53 | 3.7 | | | | |




Detail Showing Allowance For Line Width



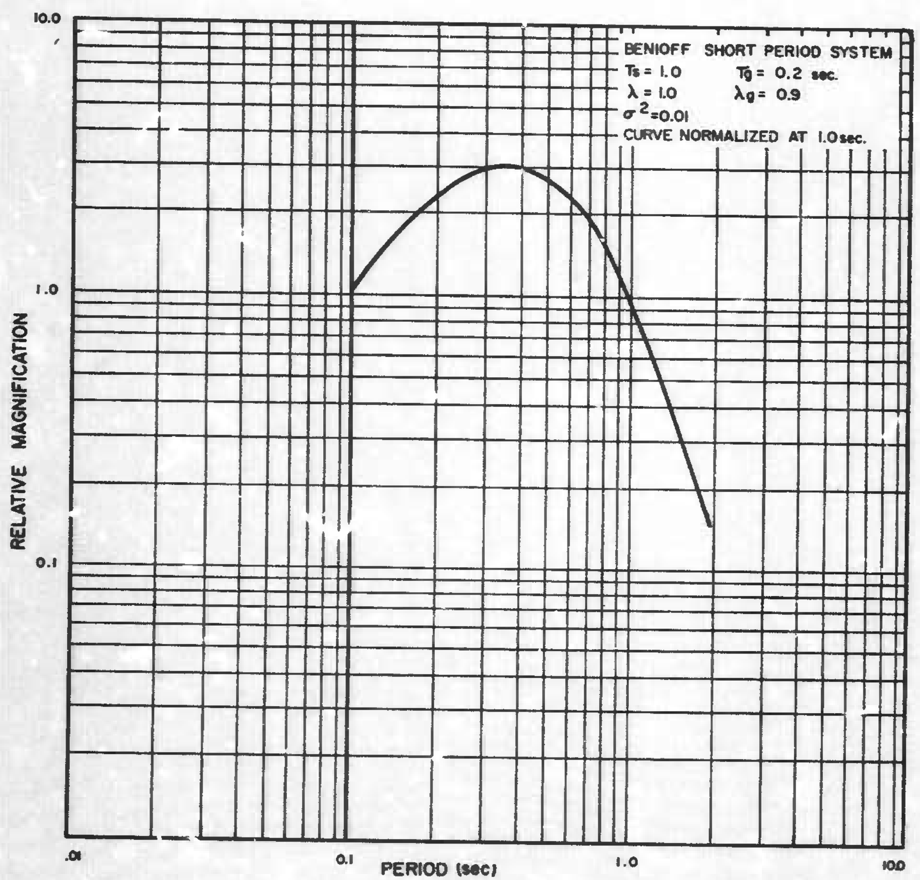

Pick time of Pn at beginning of "a" half cycle.

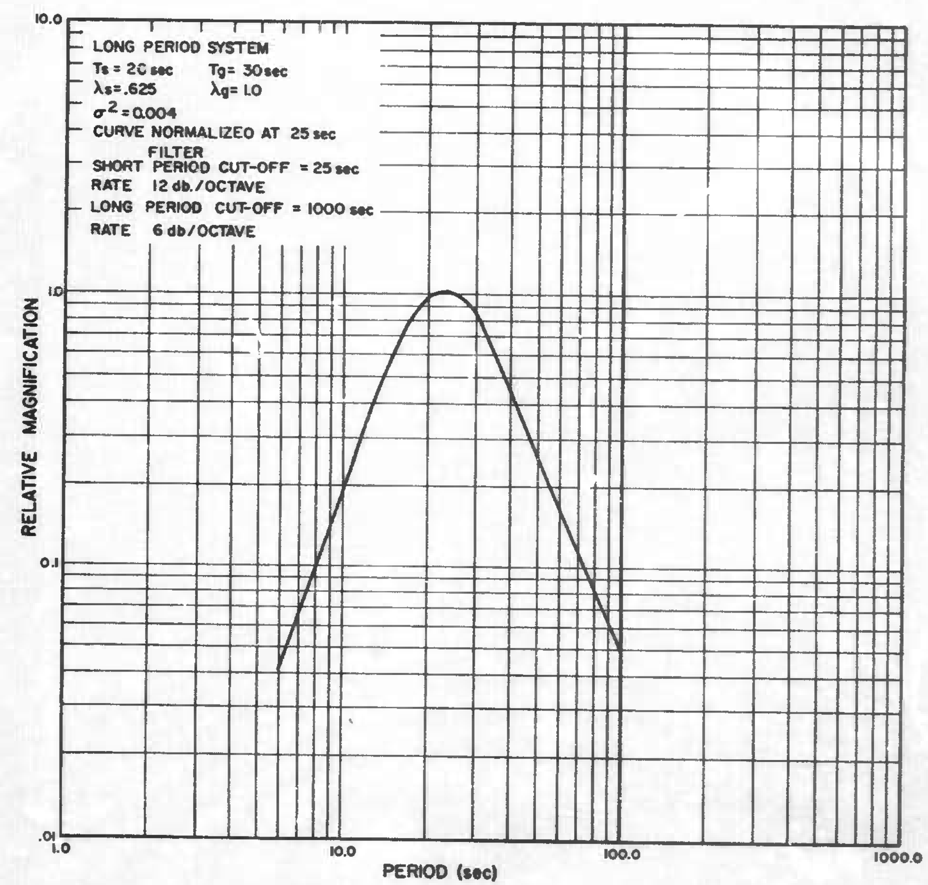
Pick amplitude of Pn as maximum "$d/_2$" within 2 or 3 cycles of "c".

Pick amplitudes of Pg and Lg at maximum of corresponding motion.

Seismic Analysis Diagram

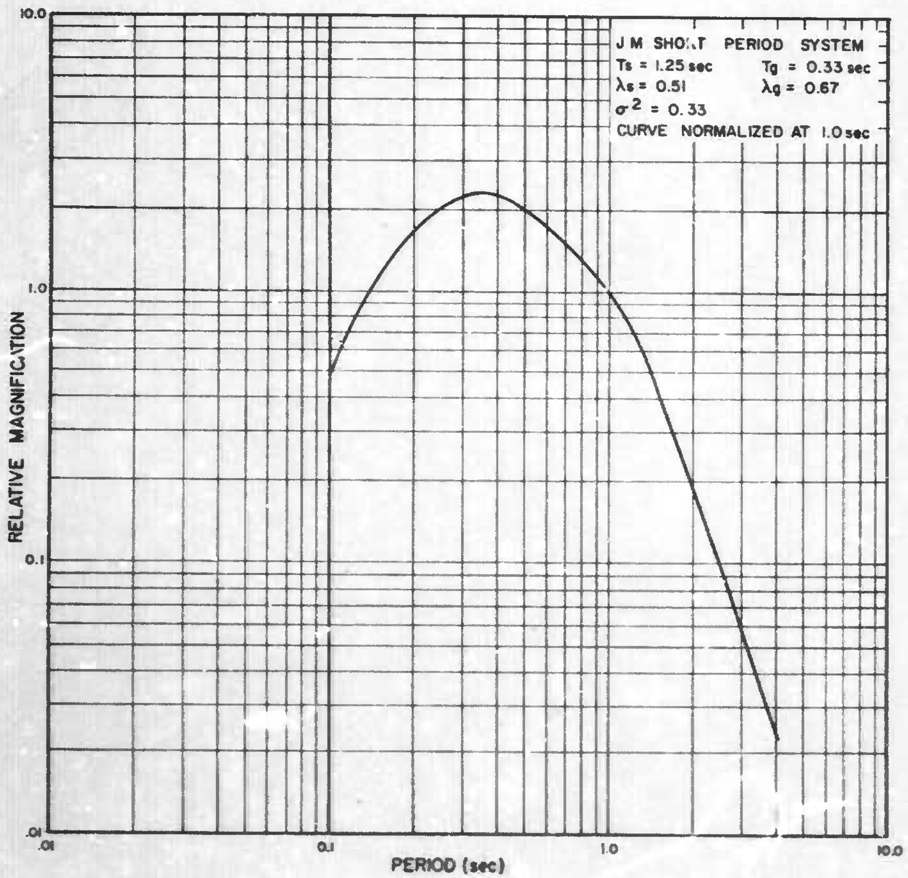
APPENDIX II(A)

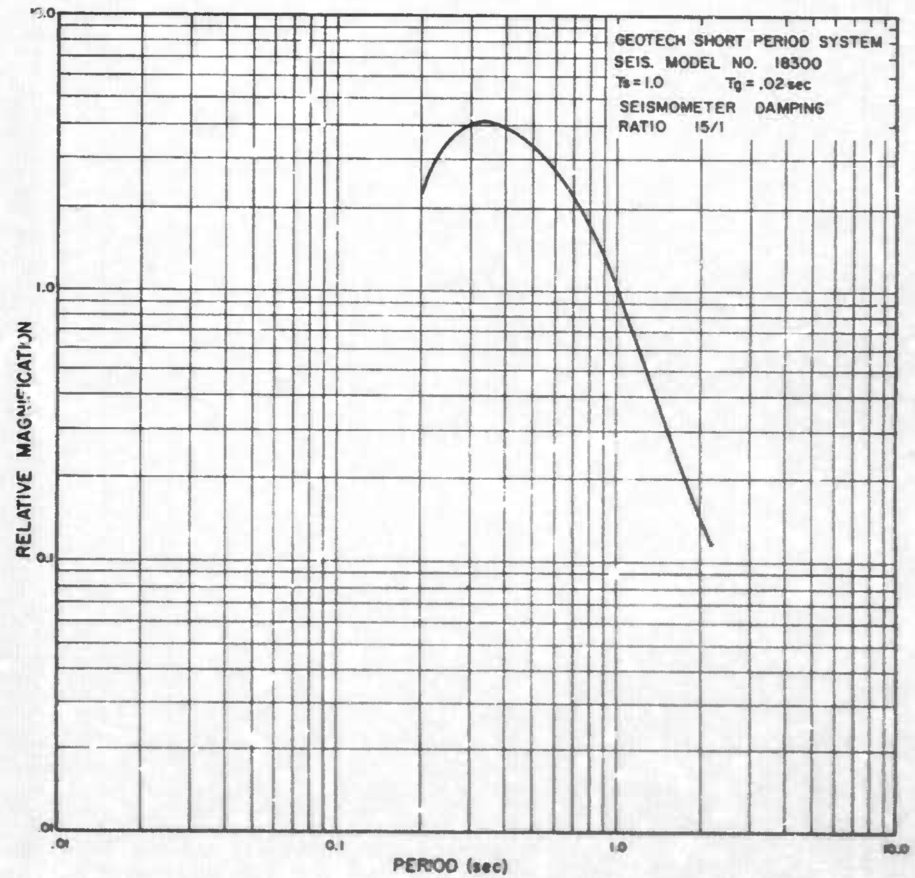



INSTRUMENT RESPONSE CURVES - LRSM

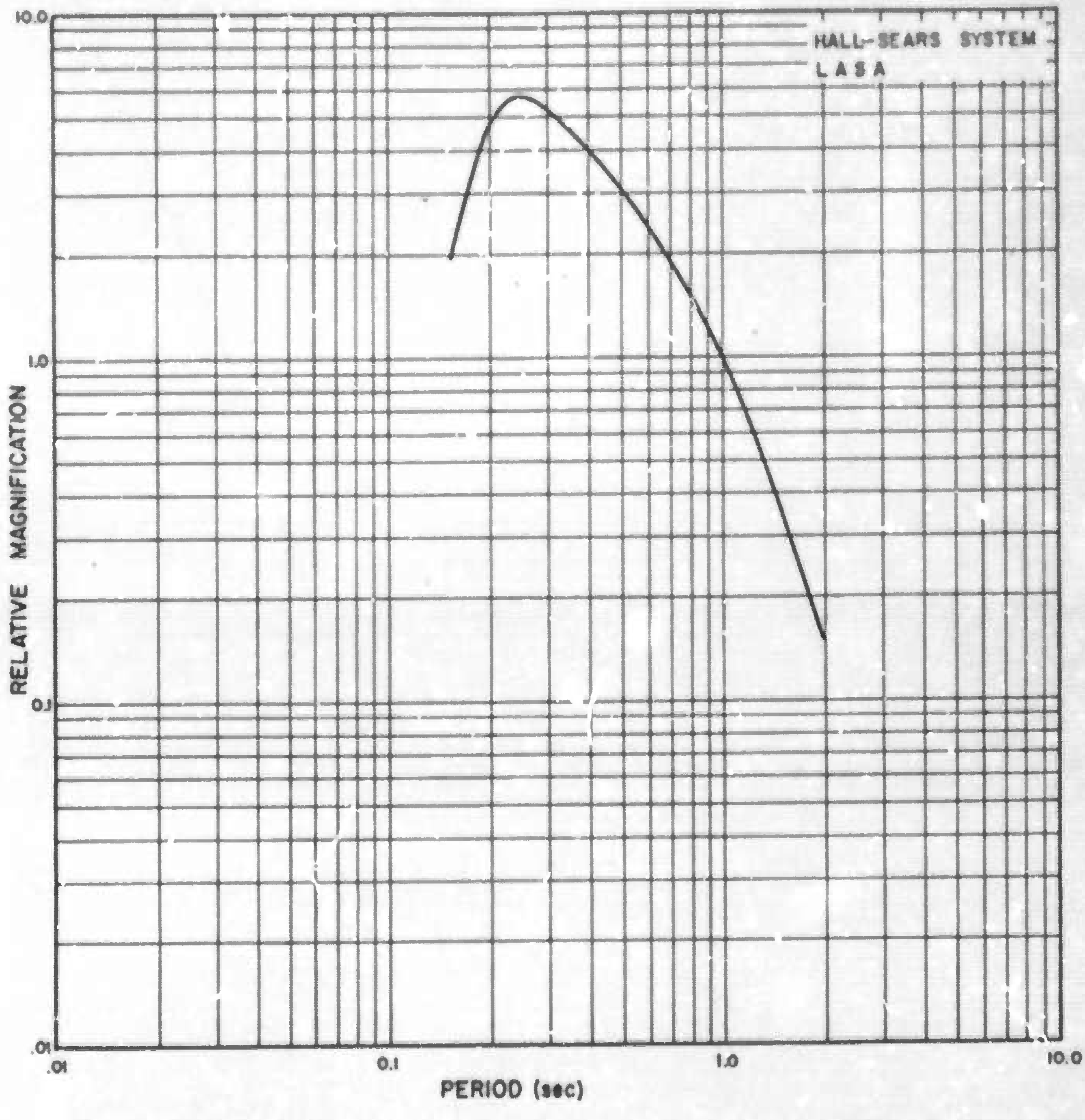
APPENDIX II(B)




INSTRUMENT RESPONSE CURVES - OTHER SHORT PERIOD

APPENDIX II(C)




INSTRUMENT RESPONSE CURVE - LASA

APPENDIX II(D)

Unclassified
Security Classification

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|---|---|
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| 3. REPORT TITLE LONG RANGE SEISMIC MEASUREMENTS - GREELEY | |
| 4. DESCRIPTIVE NOTES (Type of report and inclusive dates) Scientific | |
| 5. AUTHOR(S) (Last name, first name, initial) Clark, Don M. | |
| 6. REPORT DATE 28 APRIL 1967 | 7a. TOTAL NO. OF PAGES; 7b. NO. OF REFS 2 |
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13. ABSTRACT

An analysis of seismological data from an underground nuclear explosion as a continuing study to provide information to aid in distinguishing between earthquakes and explosions. A table of travel-times and amplitudes of P, Pg, Lg, and surface waves are included along with other unidentified phases.

DD FORM 1 JAN 64 1473

Unclassified
Security Classification

Unclassified

Security Classification

| 14. KEY WORDS | LINK A ROLE | LINK A WT | LINK B ROLE | LINK B WT | LINK C ROLE | LINK C WT |
|---|---|---|---|---|---|---|
| Sismic Magnitude | | | | | | |
| Seismic Travel-Time | | | | | | |
| Seismic Amplitude | | | | | | |
| VELA-UNIFORM | | | | | | |
| Nuclear Tests | | | | | | |

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12. SPONSORING MILITARY ACTIVITY: Enter the name of the departmental project office or laboratory sponsoring *(paying for)* the research and development. Include address.

13. ABSTRACT: Enter an abstract giving a brief and factual summary of the document indicative of the report, even though it may also appear elsewhere in the body of the technical report. If additional space is required, a continuation sheet shall be attached.

It is highly desirable that the abstract of classified reports be unclassified. Each paragraph of the abstract shall end with an indication of the military security classification of the information in the paragraph, represented as *(TS)*, *(S)*, *(C)*, or *(U)*.

There is no limitation on the length of the abstract. However, the suggested length is from 150 to 225 words.

14. KEY WORDS: Key words are technically meaningful terms or short phrases that characterize a report and may be used as index entries for cataloging the report. Key words must be selected so that no security classification is required. Identifiers, such as equipment model designation, trade name, military project code name, geographic location, may be used as key words but will be followed by an indication of technical context. The assignment of links, rules, and weights is optional.

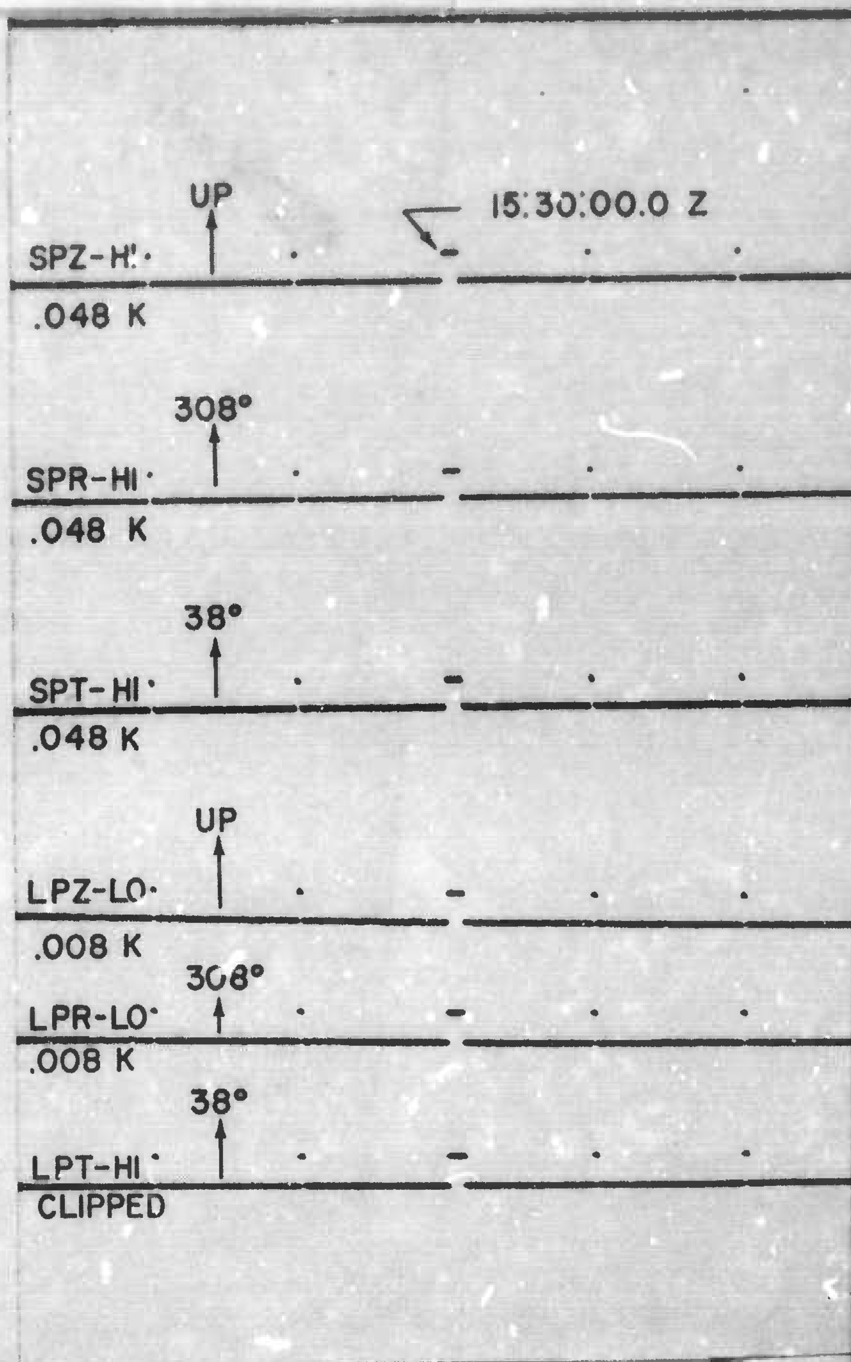
GREELEY

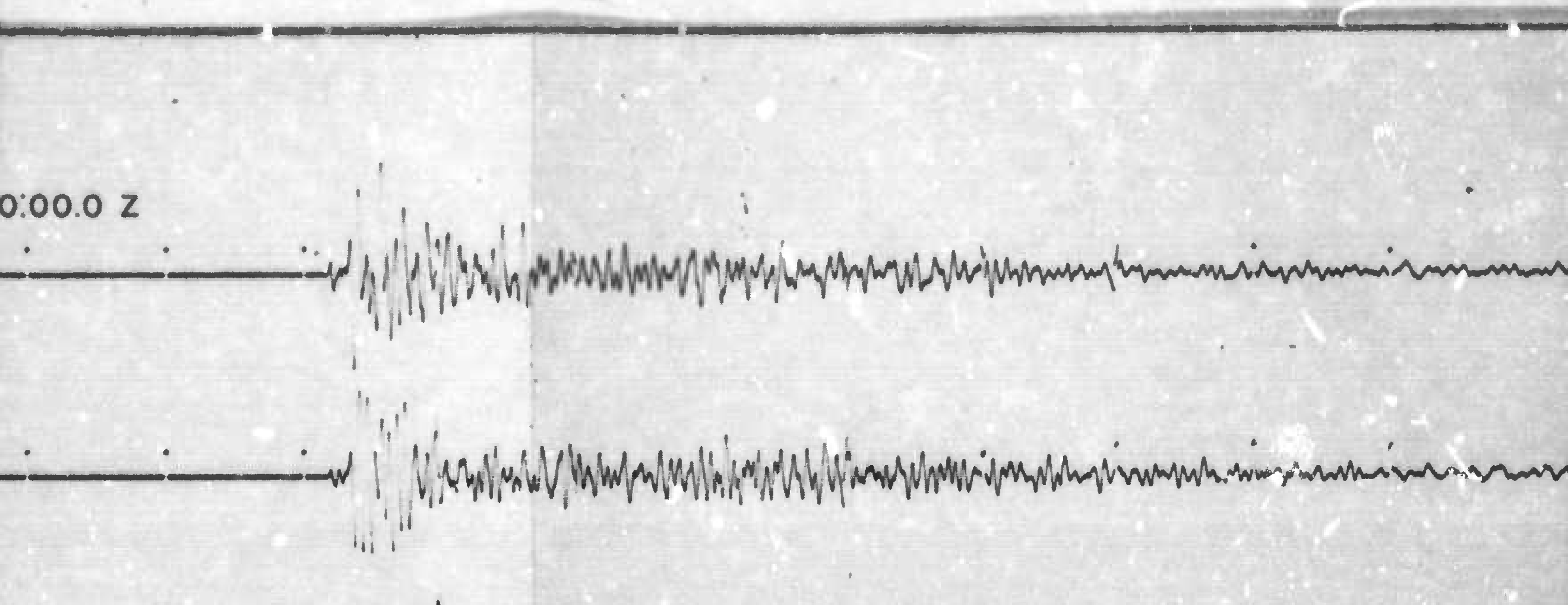
MN – NV

MINA, NEVADA

20 DECEMBER 1966

$\Delta$ = 198 km



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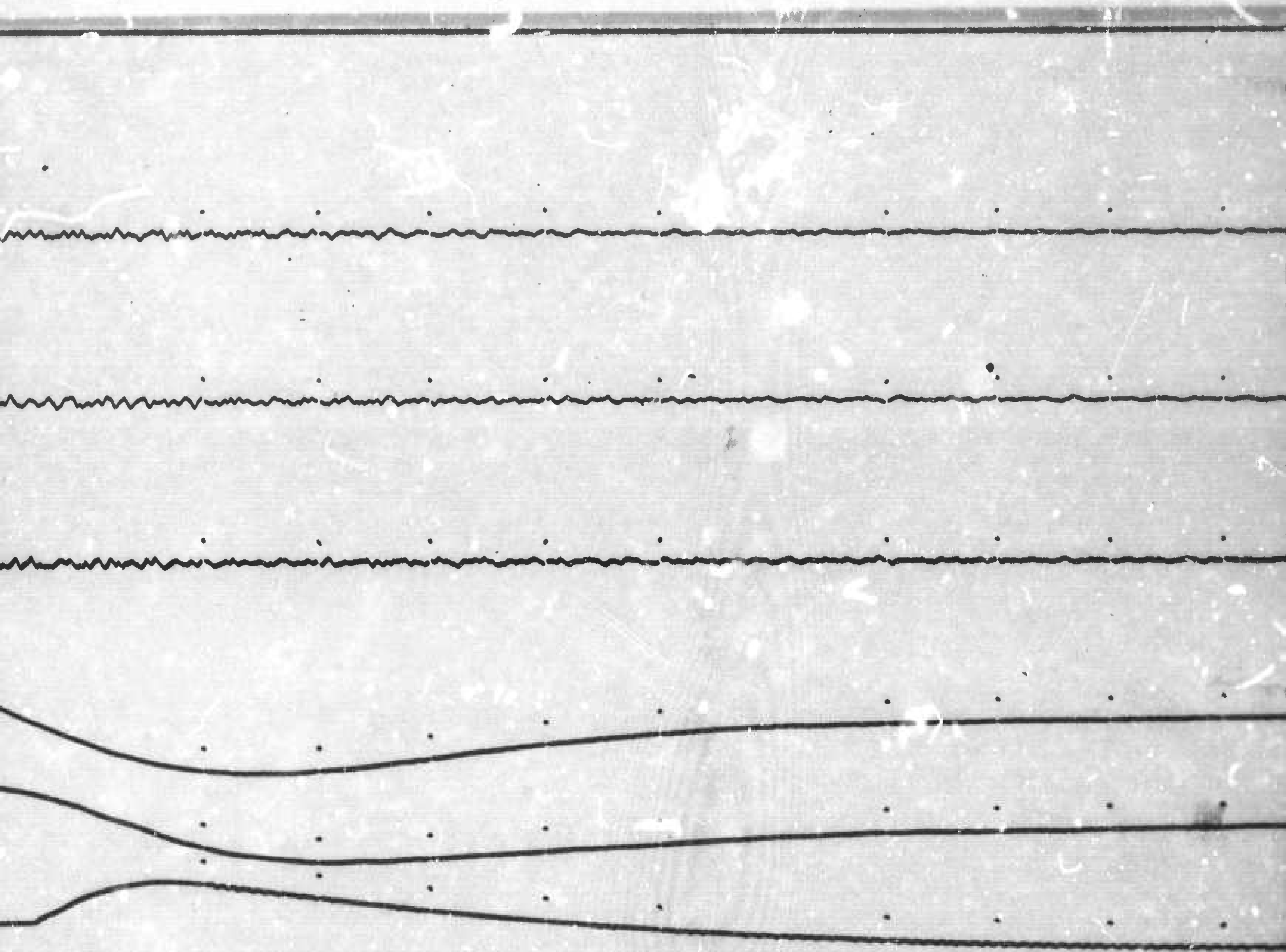


3

4

GREELEY

MO-ID

MOUNTAIN HOME, IDAHO

20 DECEMBER 1966

$\Delta = 641$ km.

UP 15:30:50.0Z

SPZ-HI

0.425K

359°

SPR-HI

0.447K

89°

SPT-HI

0.382K

UP

LPZ-HI

0.146K

359°

LPR-HI

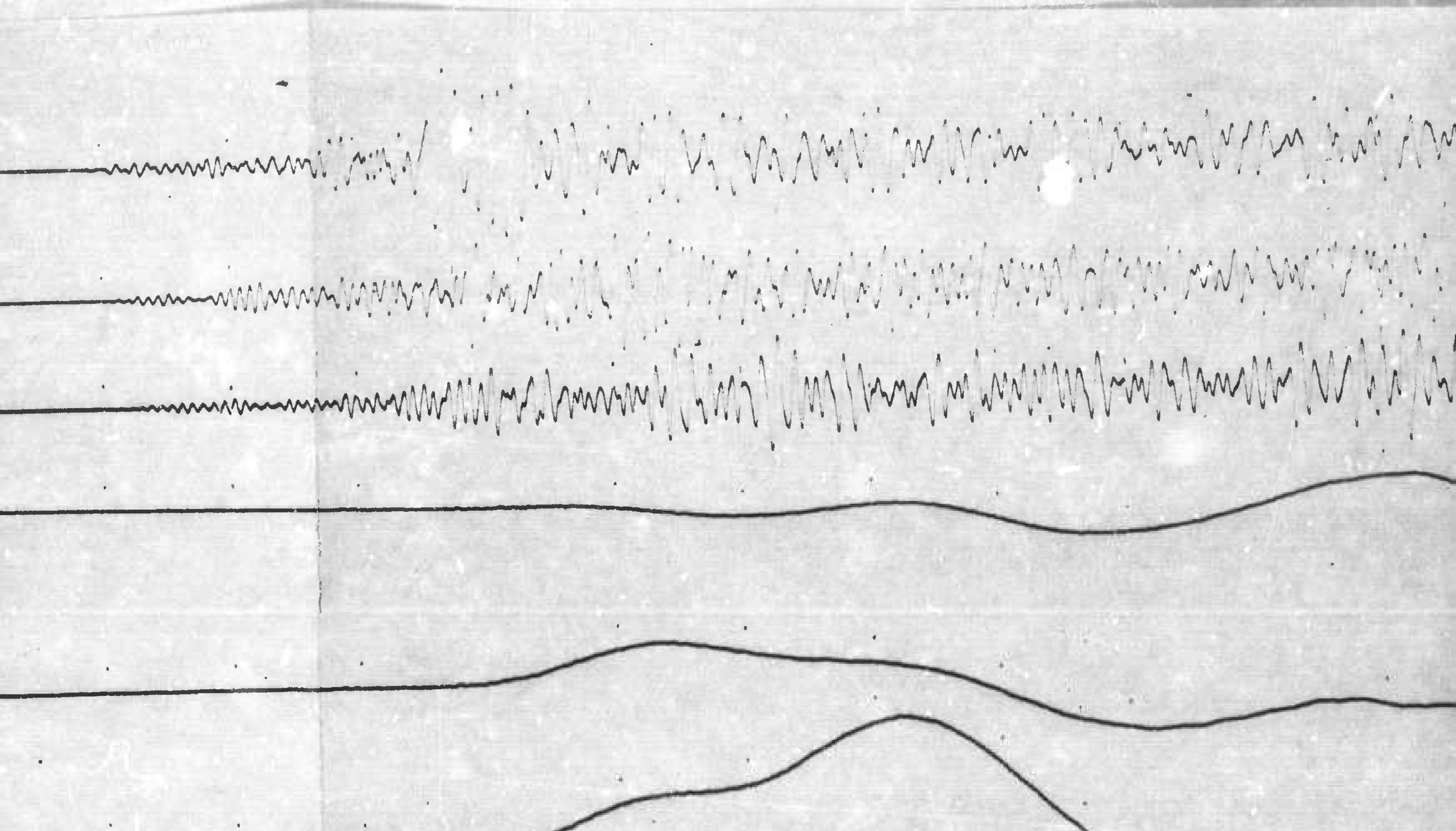
0.139K

89°

LPT-HI

0.135K

1



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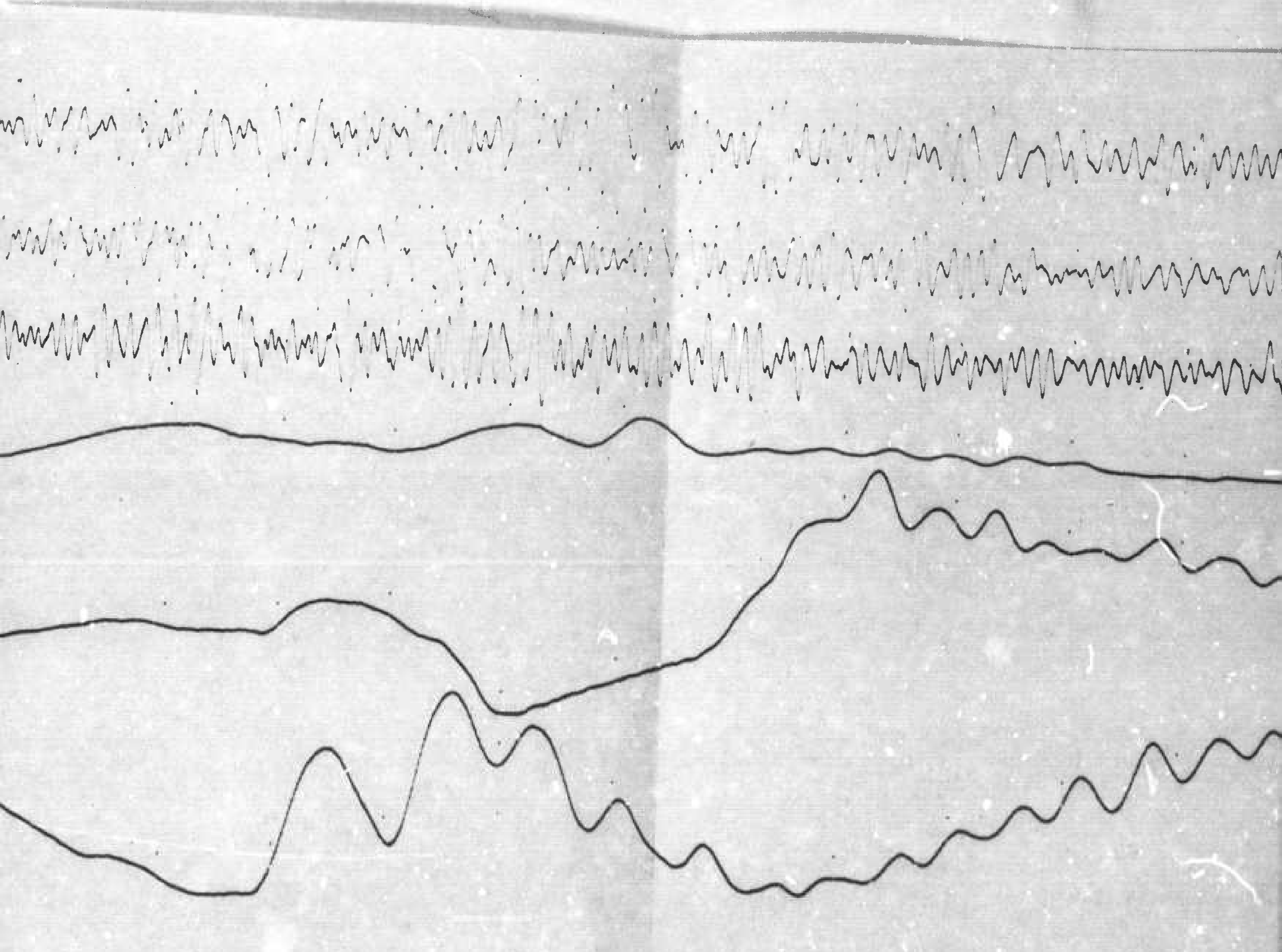

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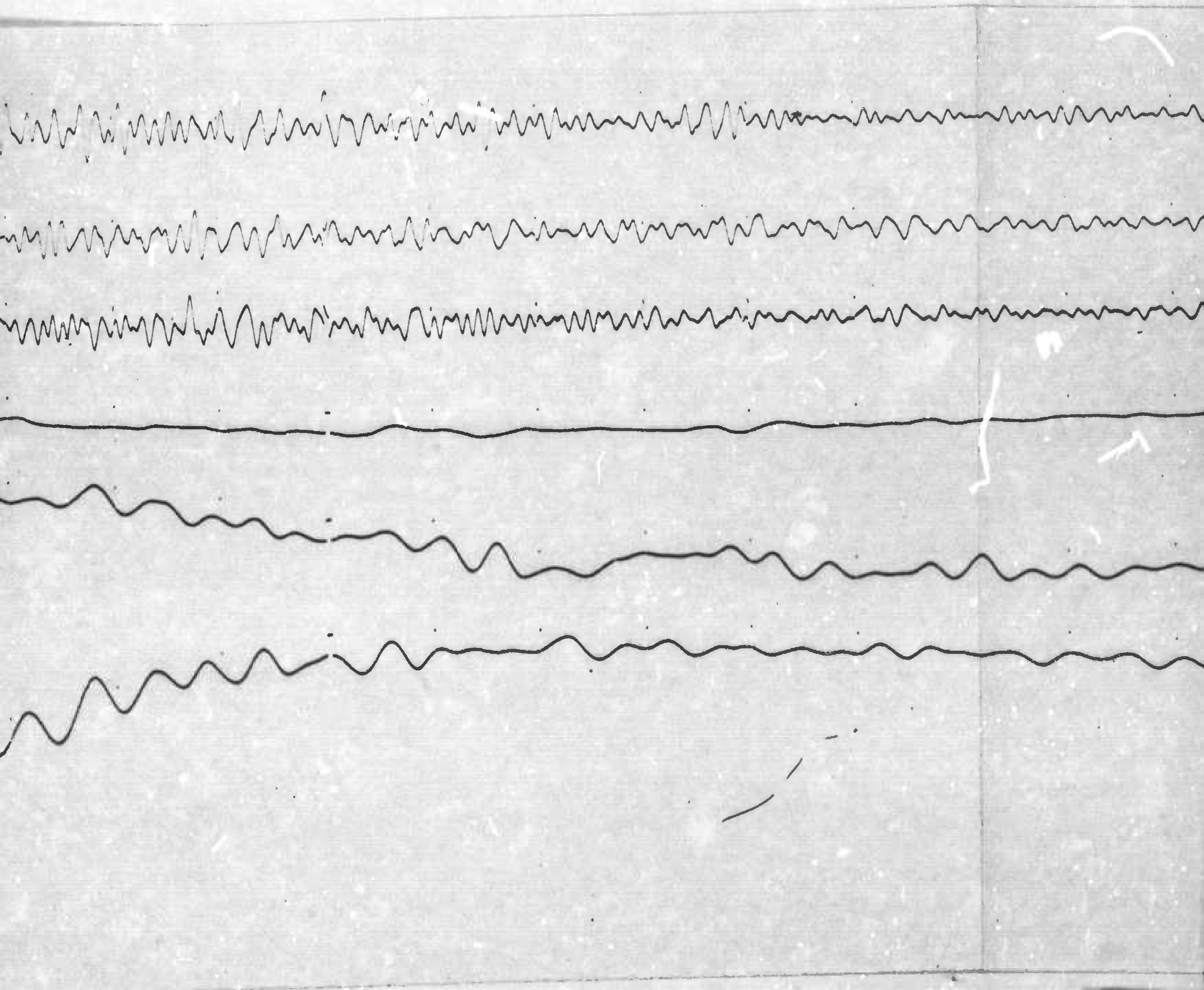

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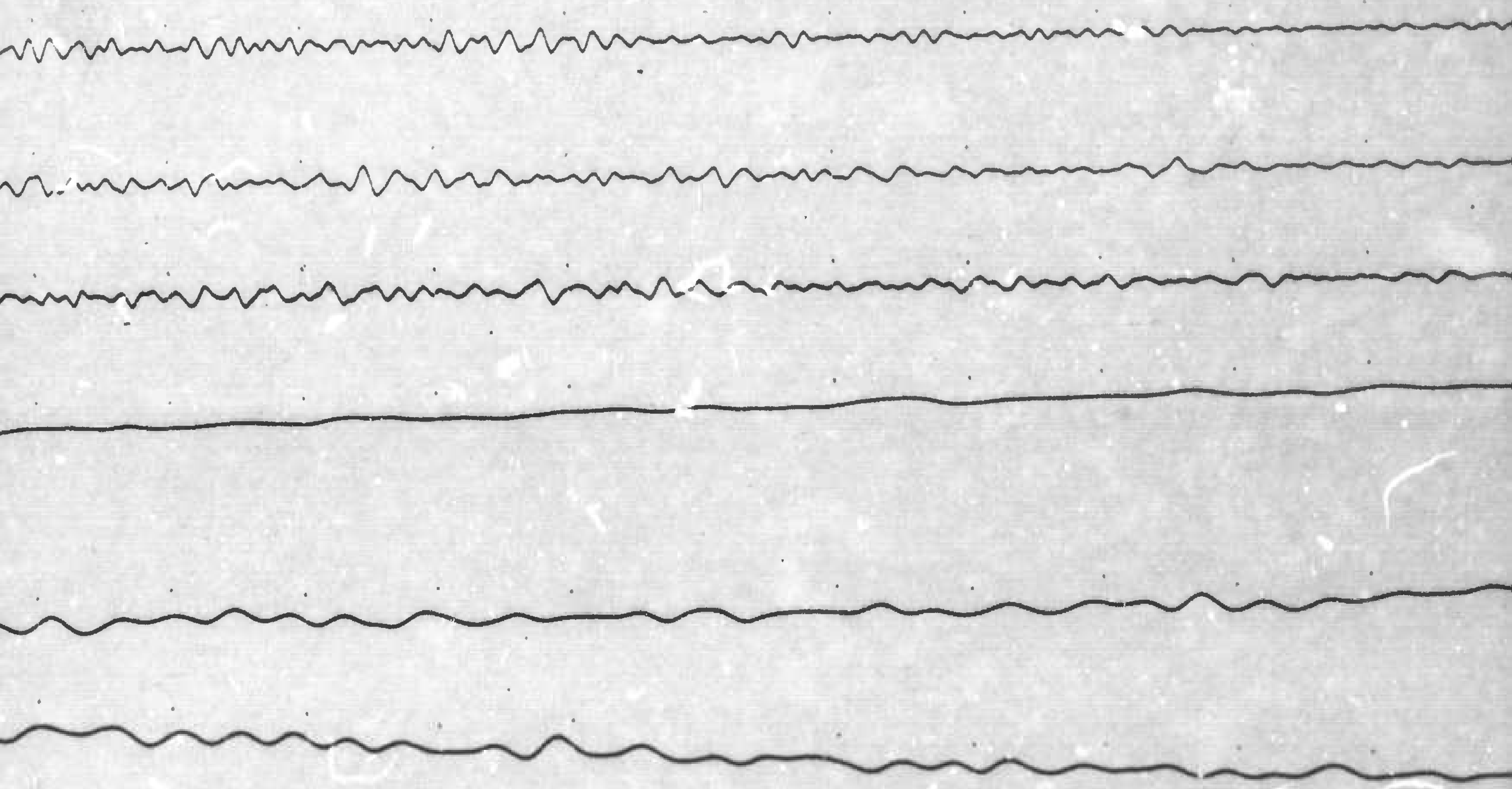

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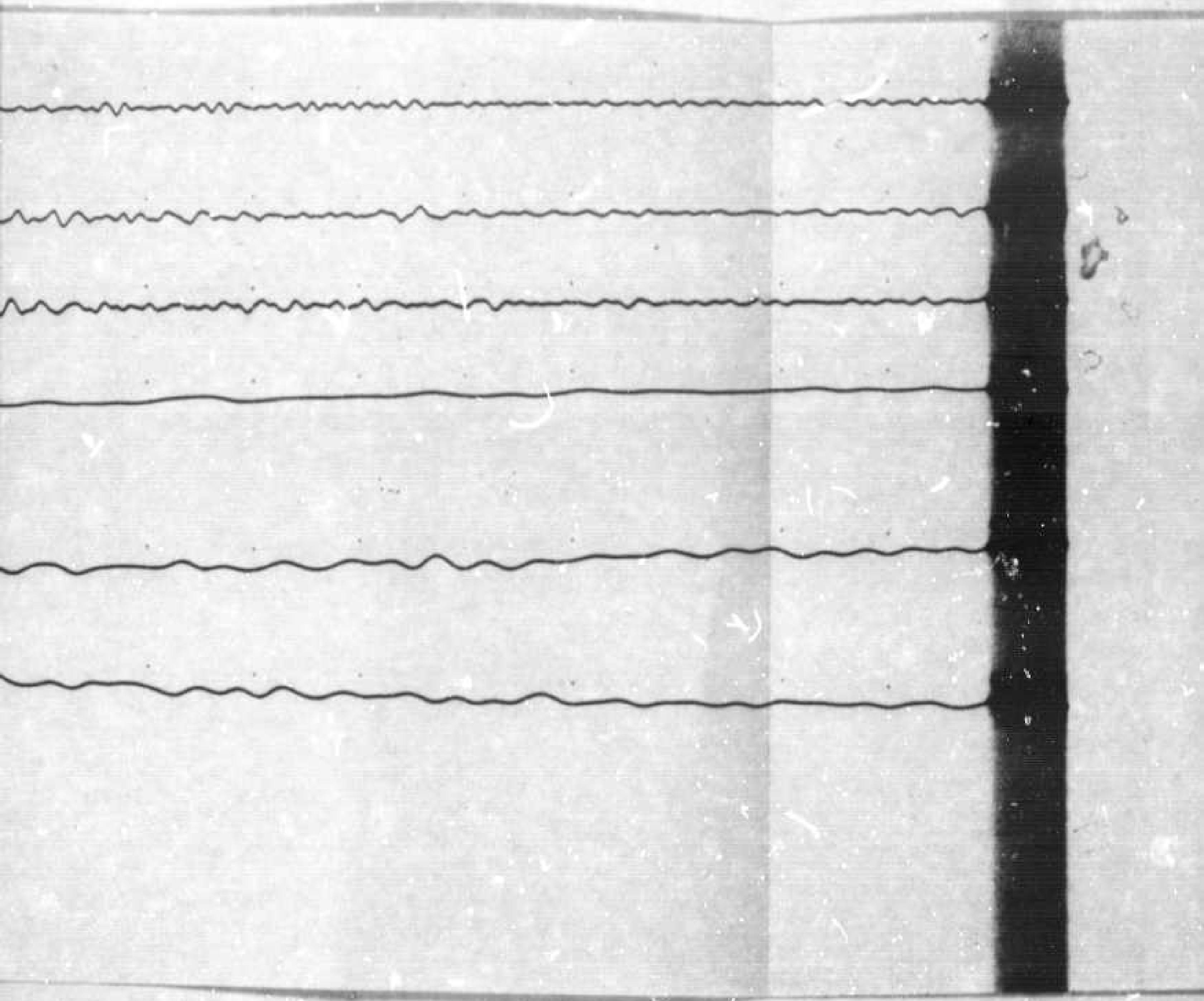


6

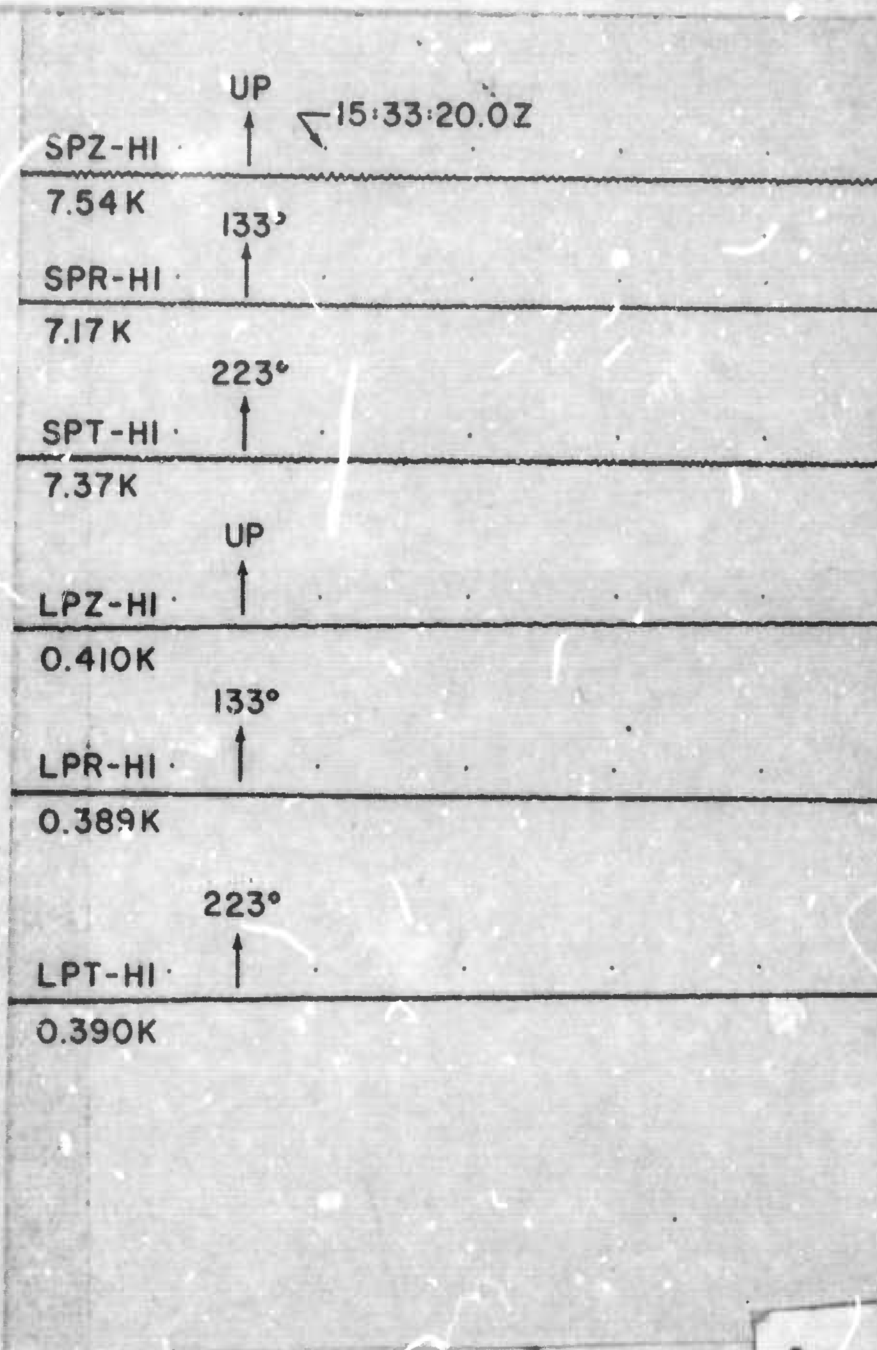
GREELEY

KC–MO

KANSAS CITY, MISSOURI

20 DECEMBER 1966

Δ = 1910 km.

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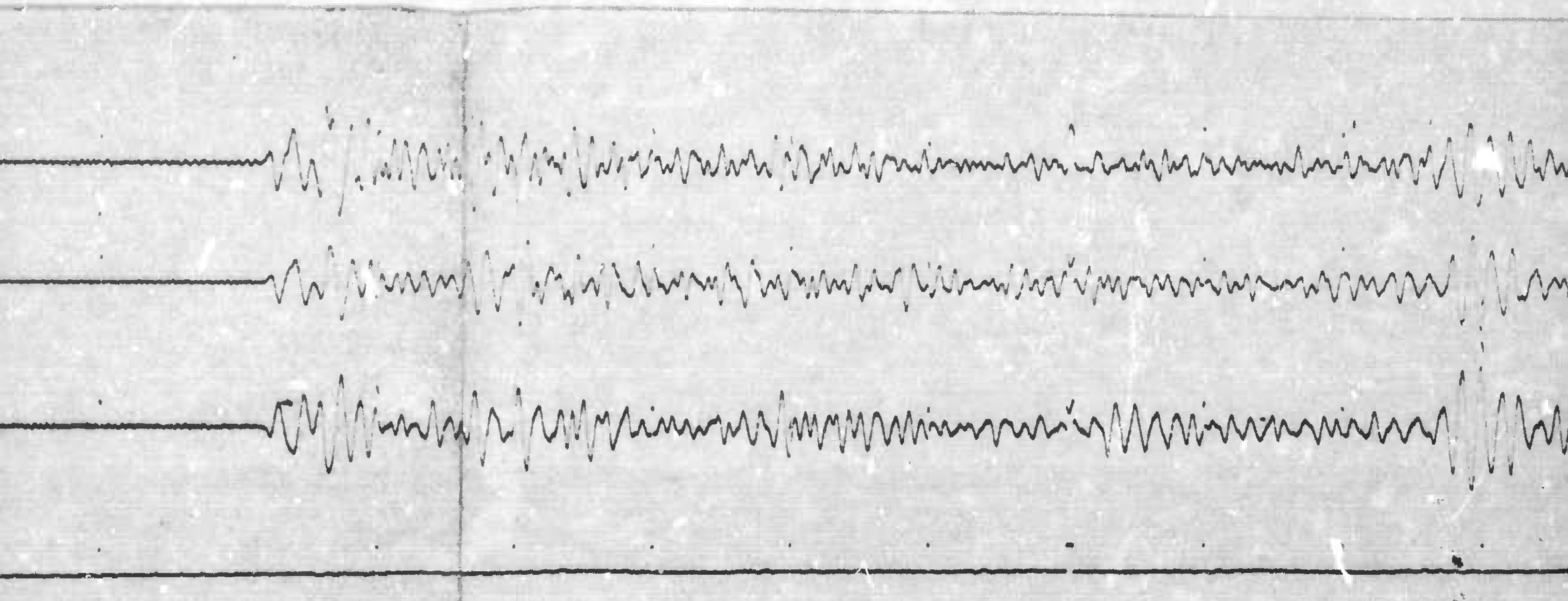

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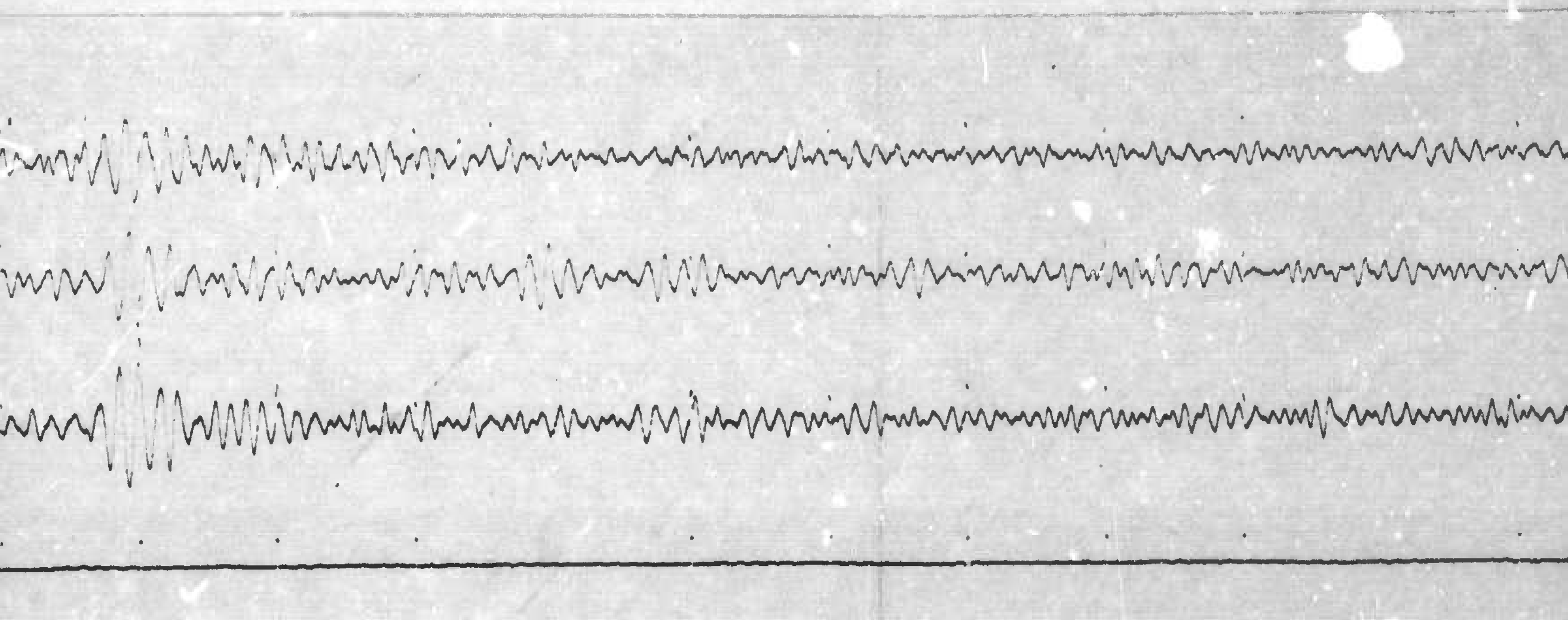

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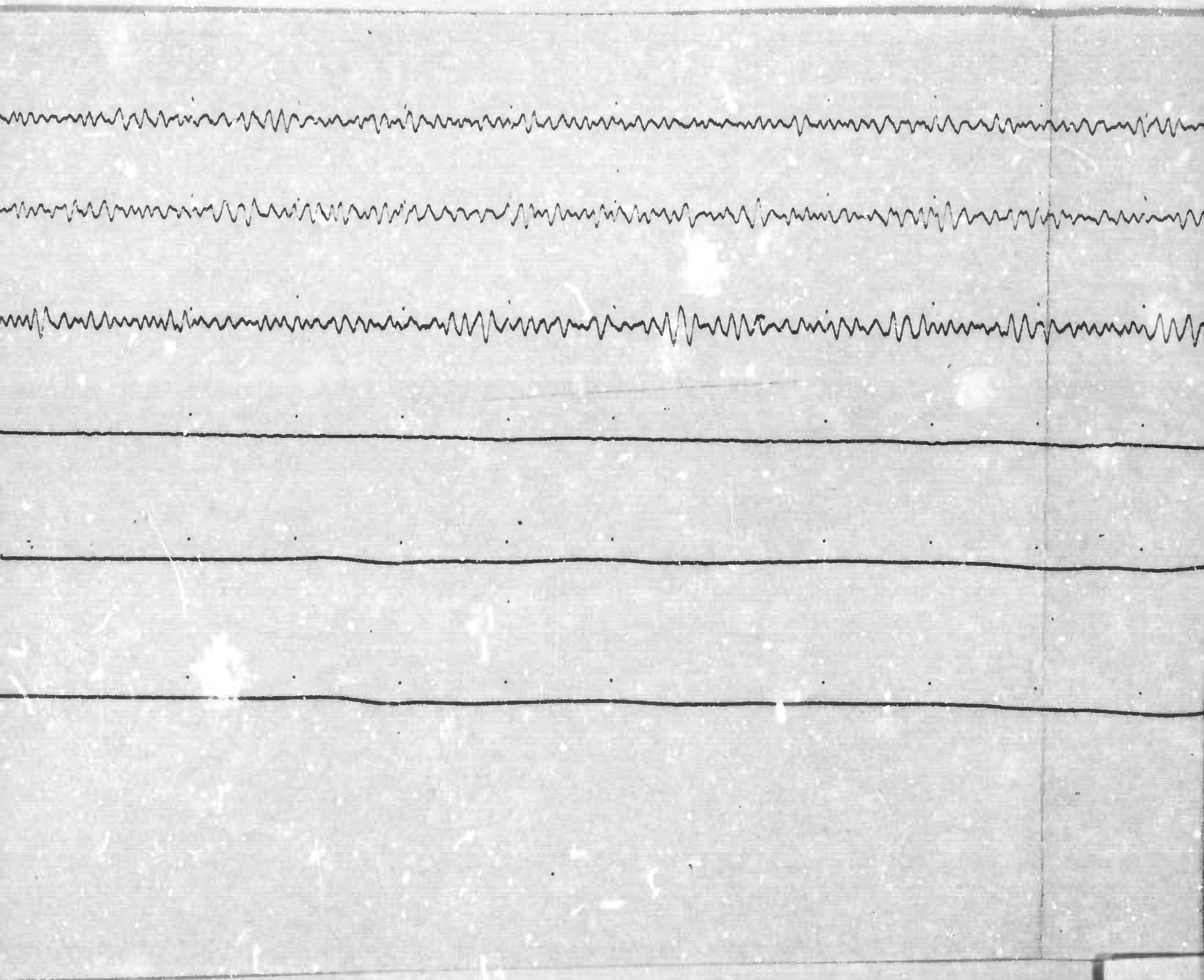

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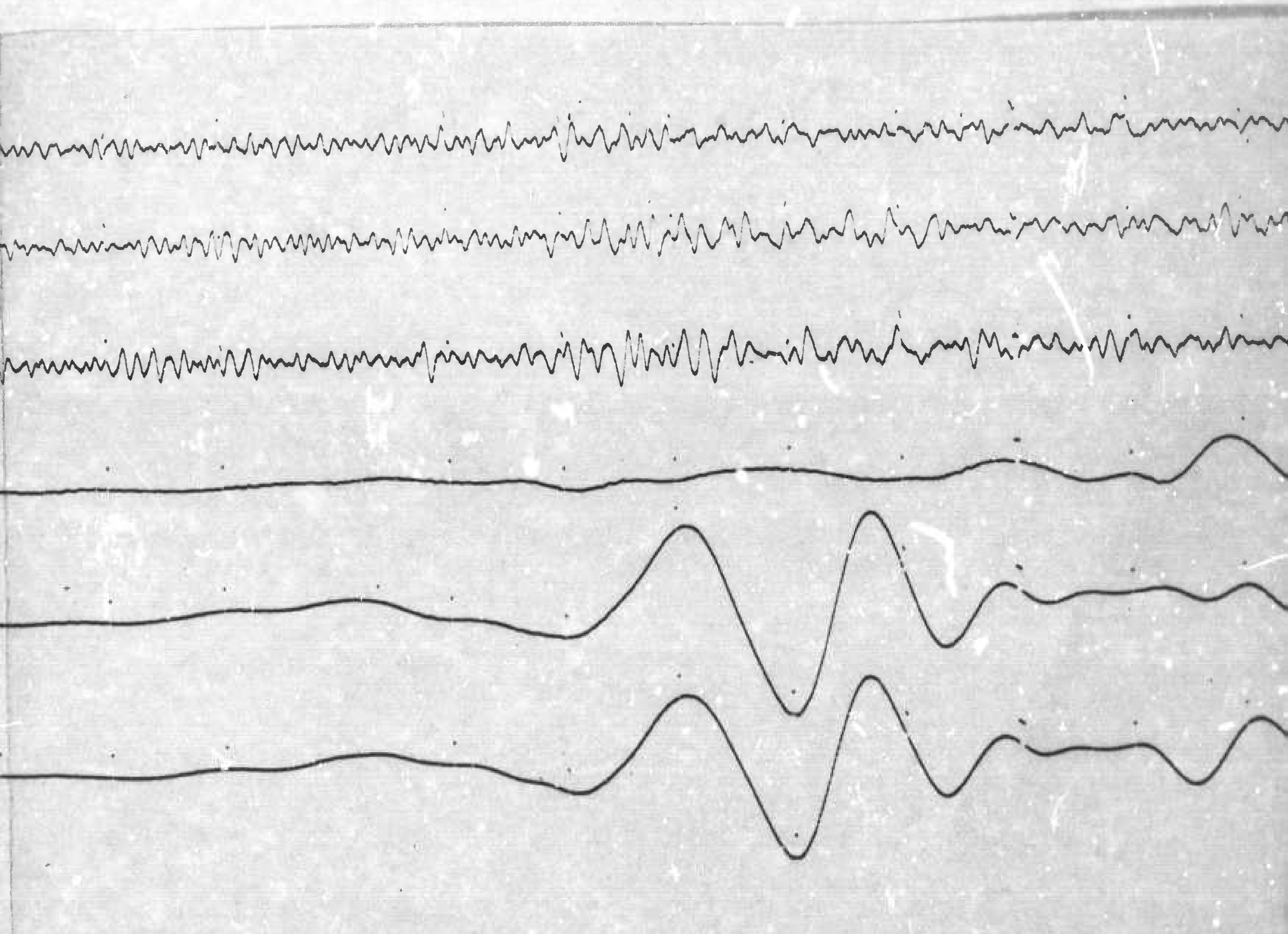

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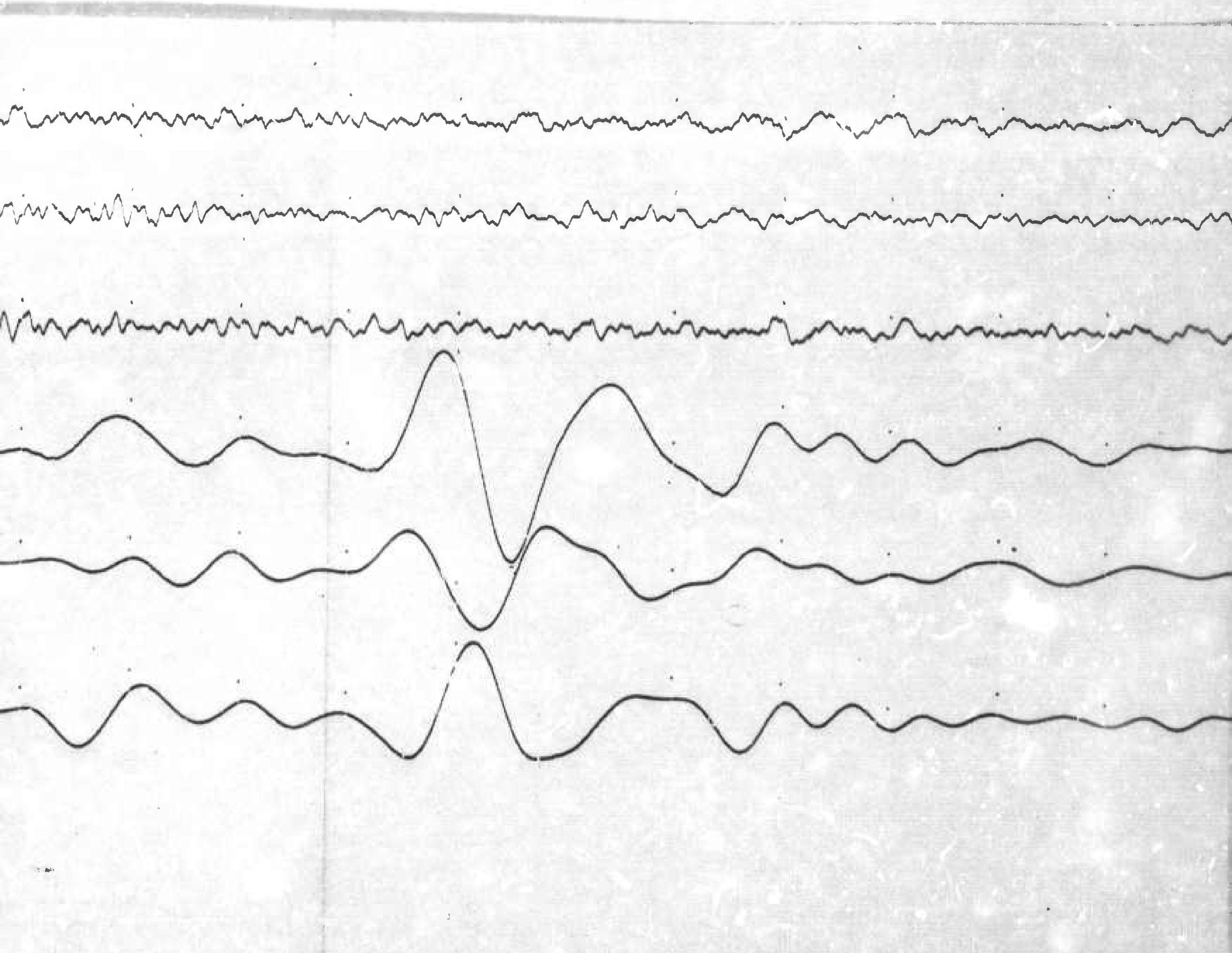

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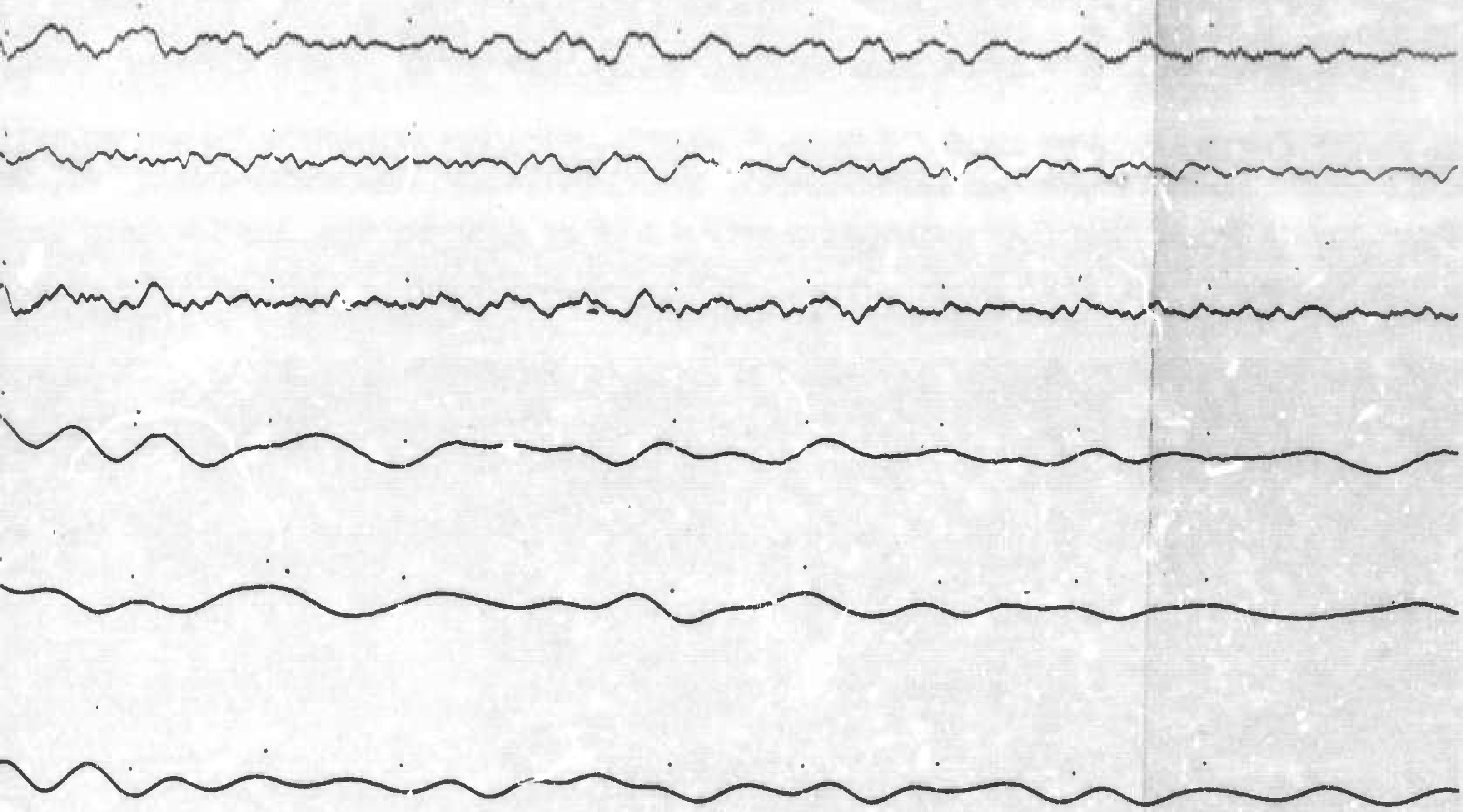


7

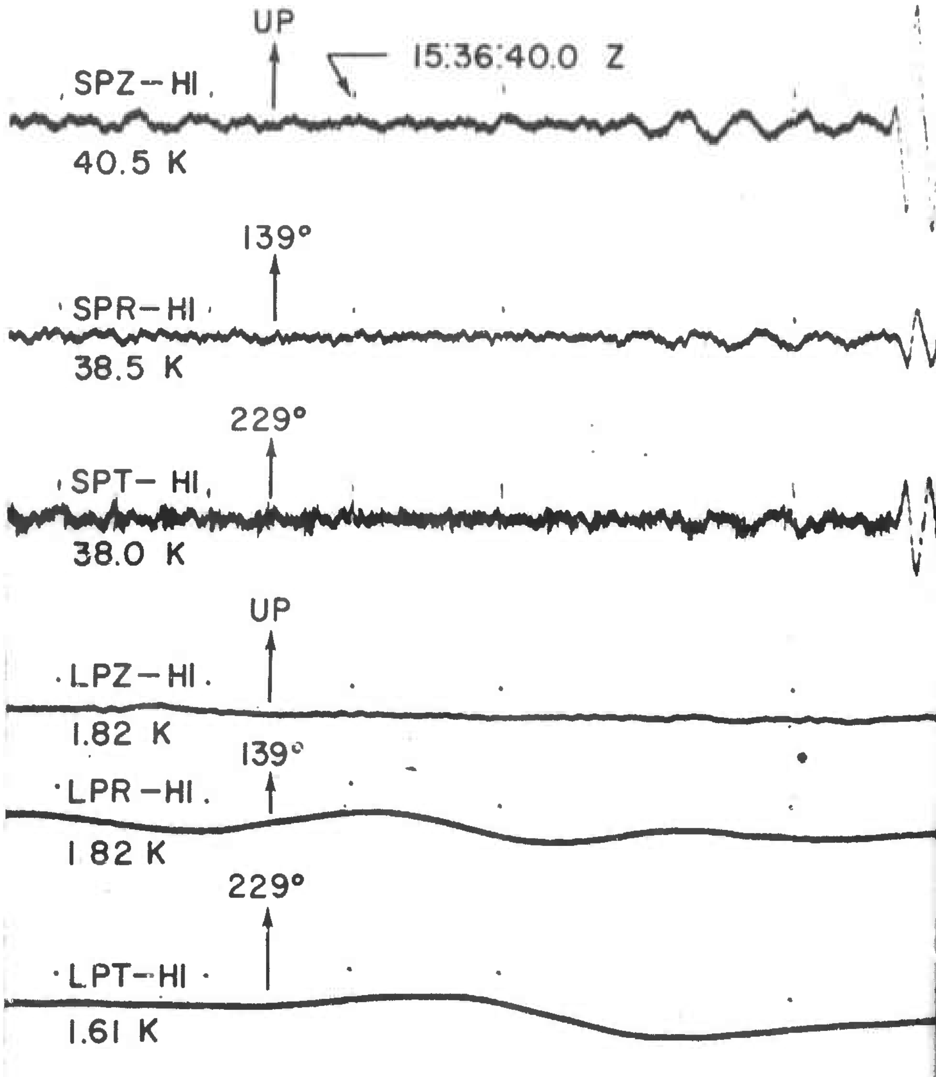
GREELEY

SV3QB

SCHEFFERVILLE, QUEBEC

20 DECEMBER 1966

Δ = 4195 km

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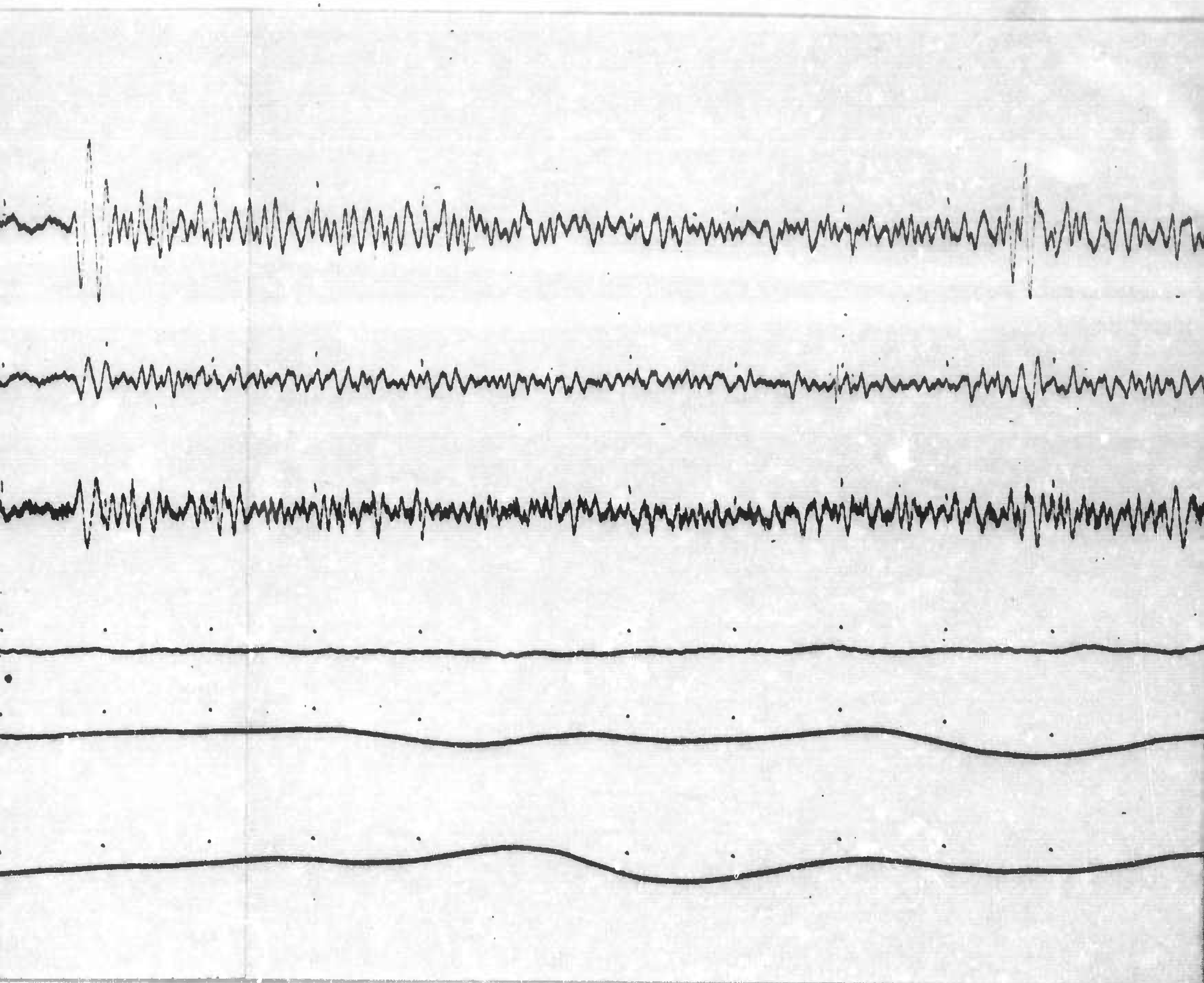

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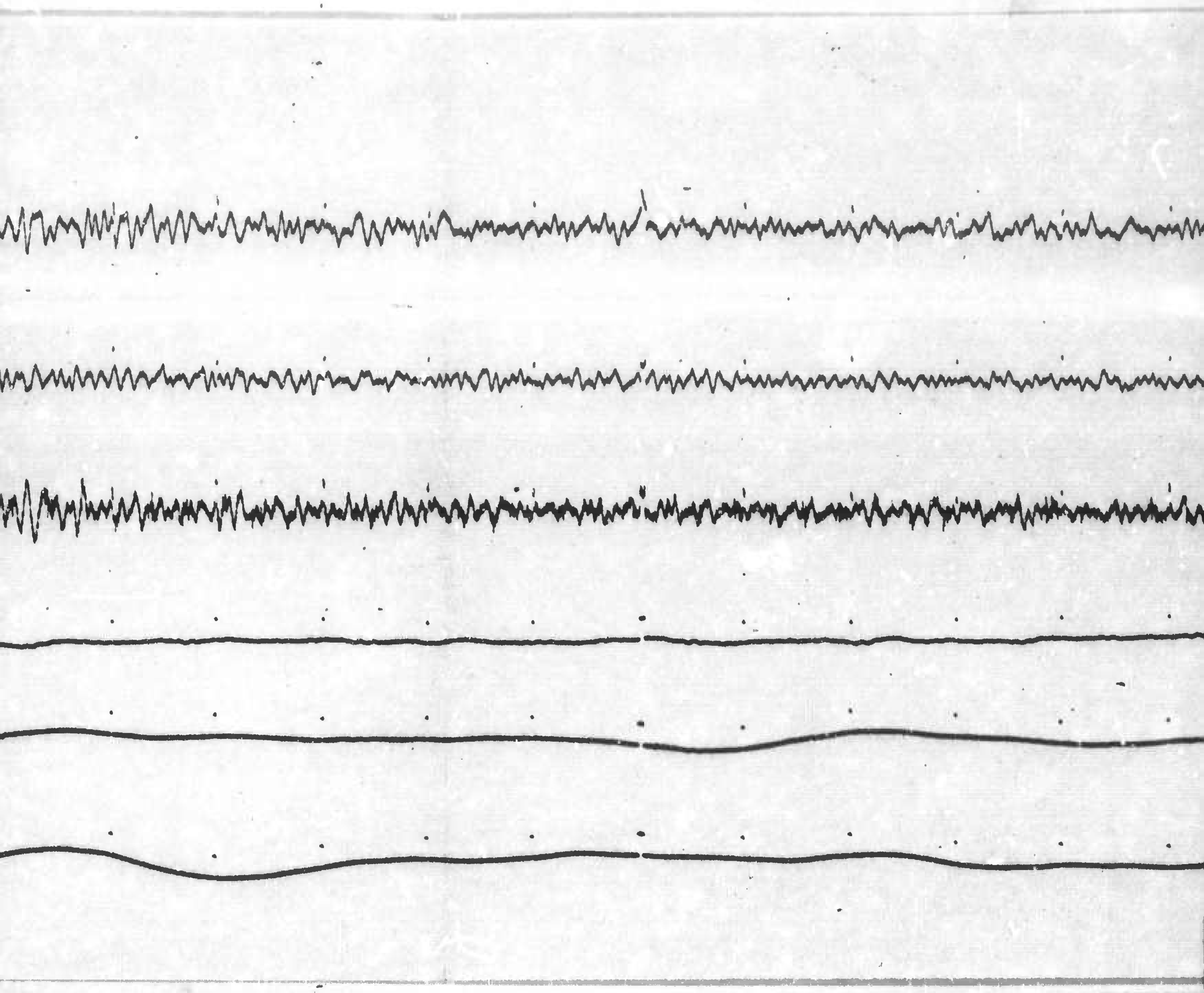

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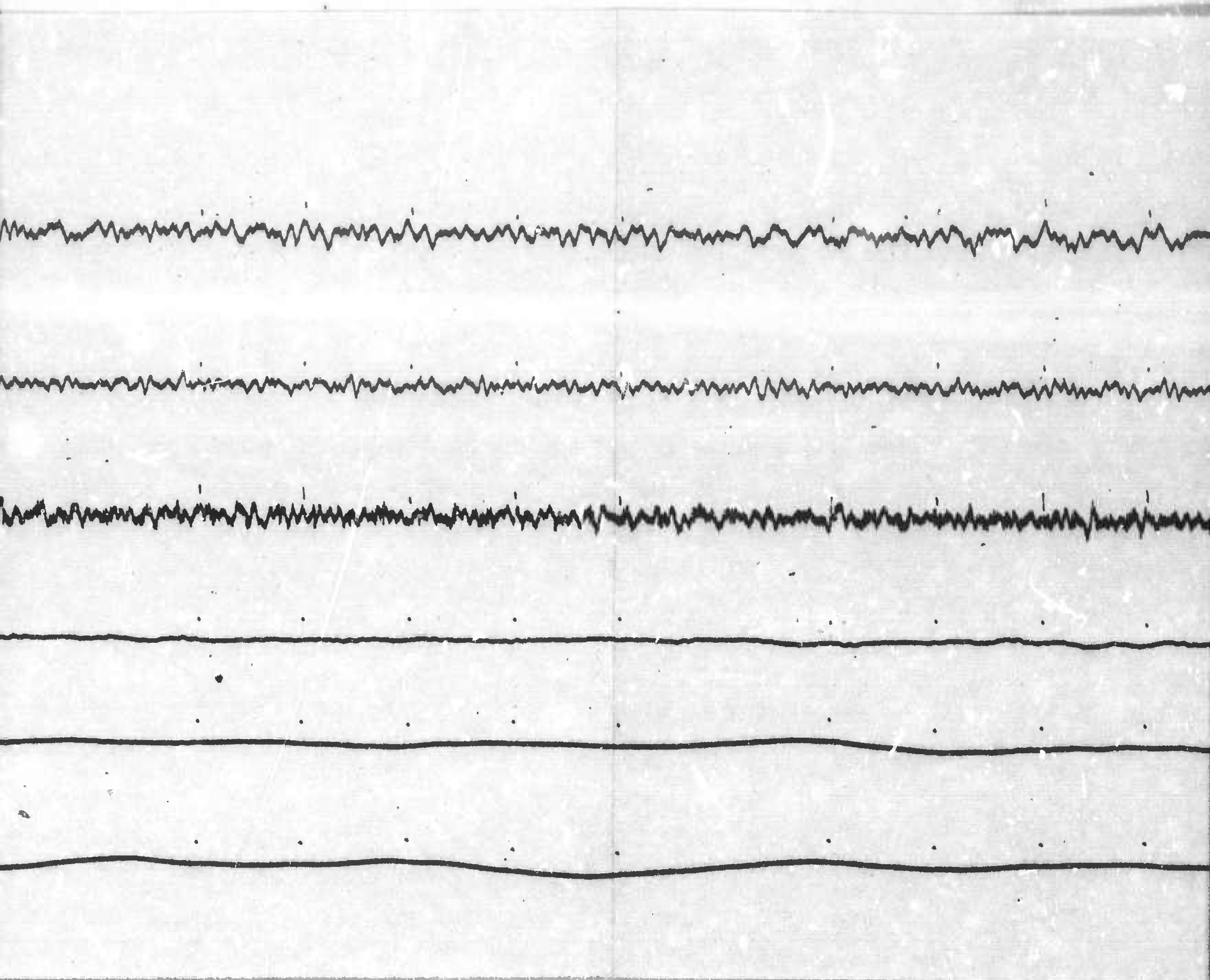

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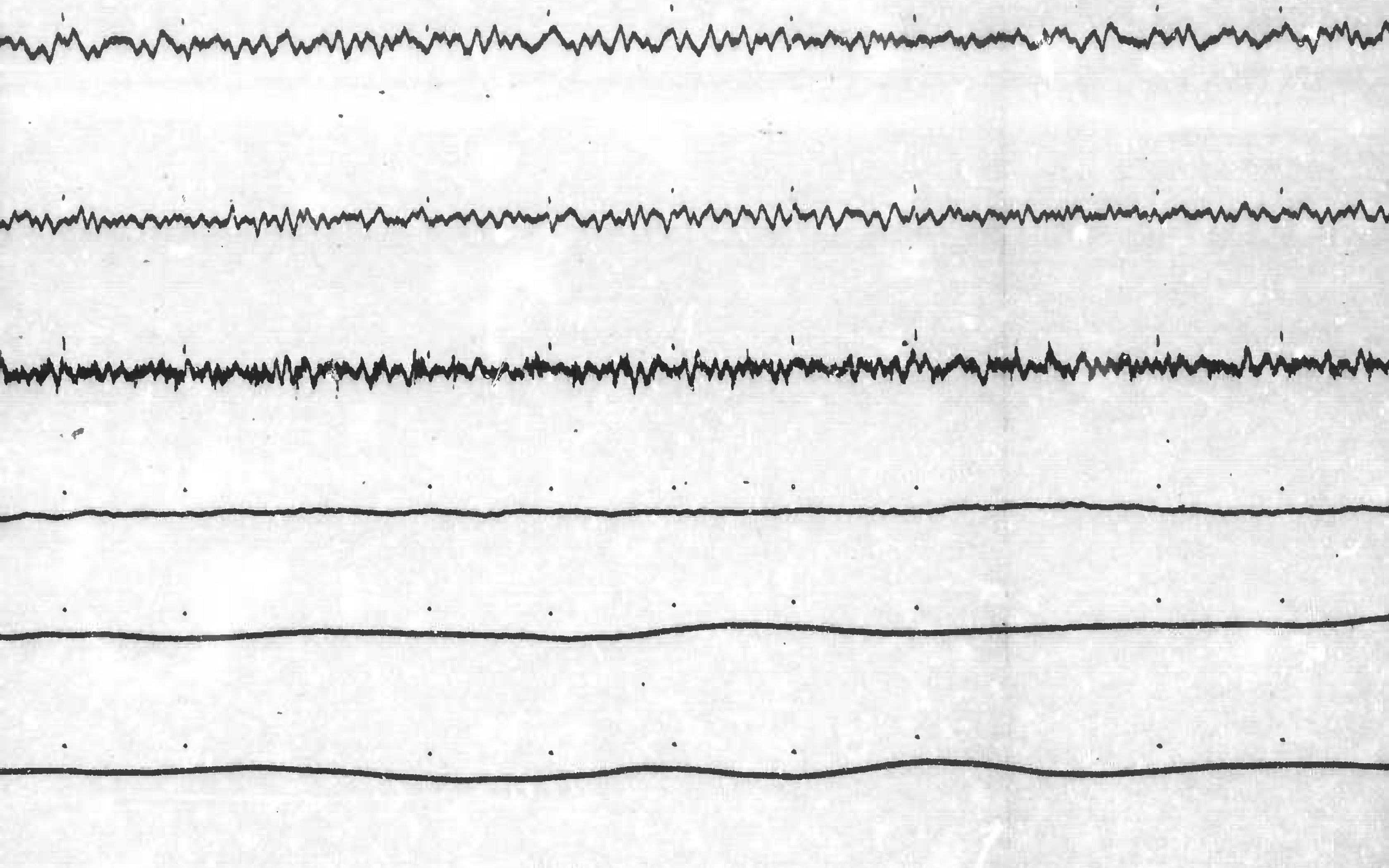

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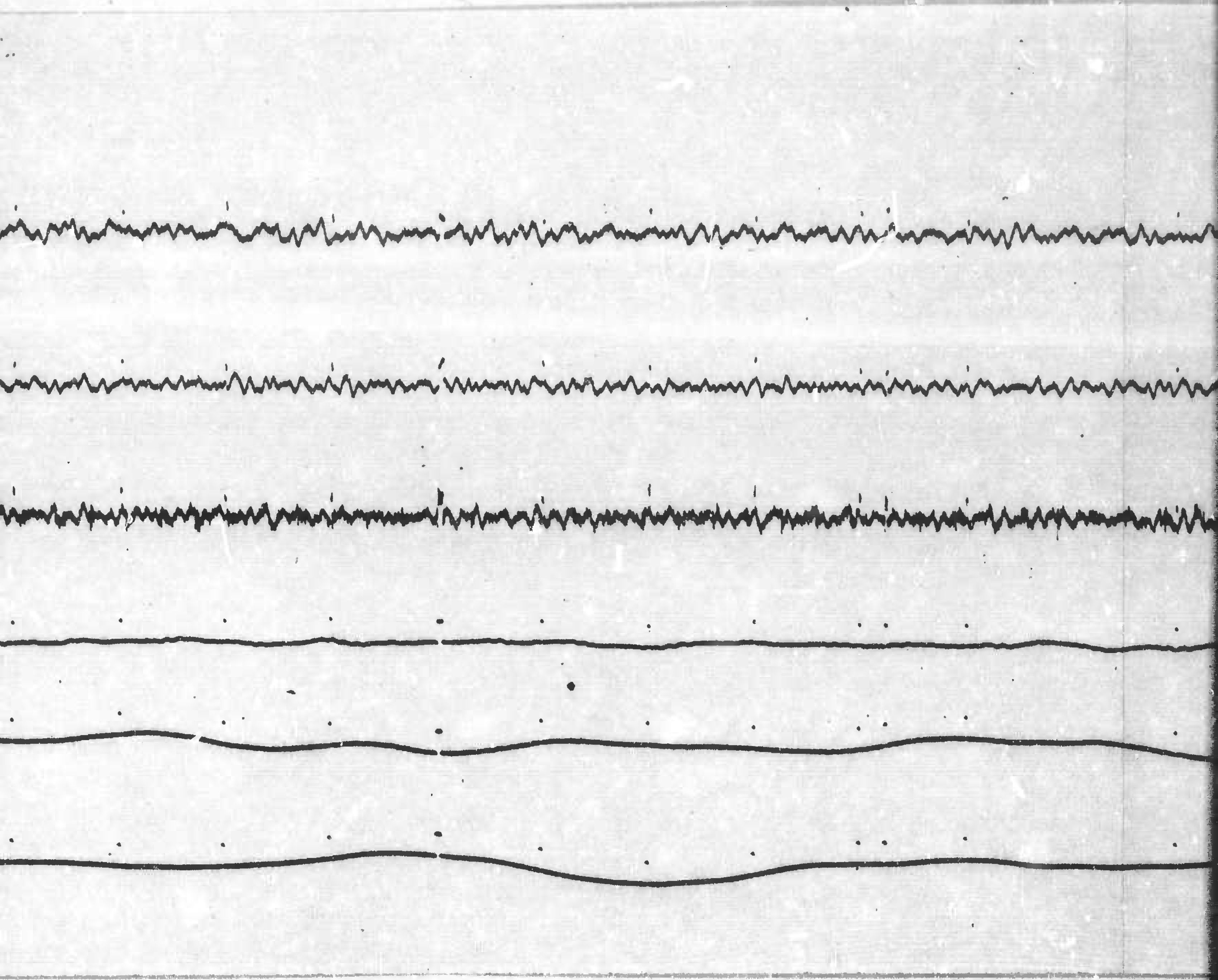

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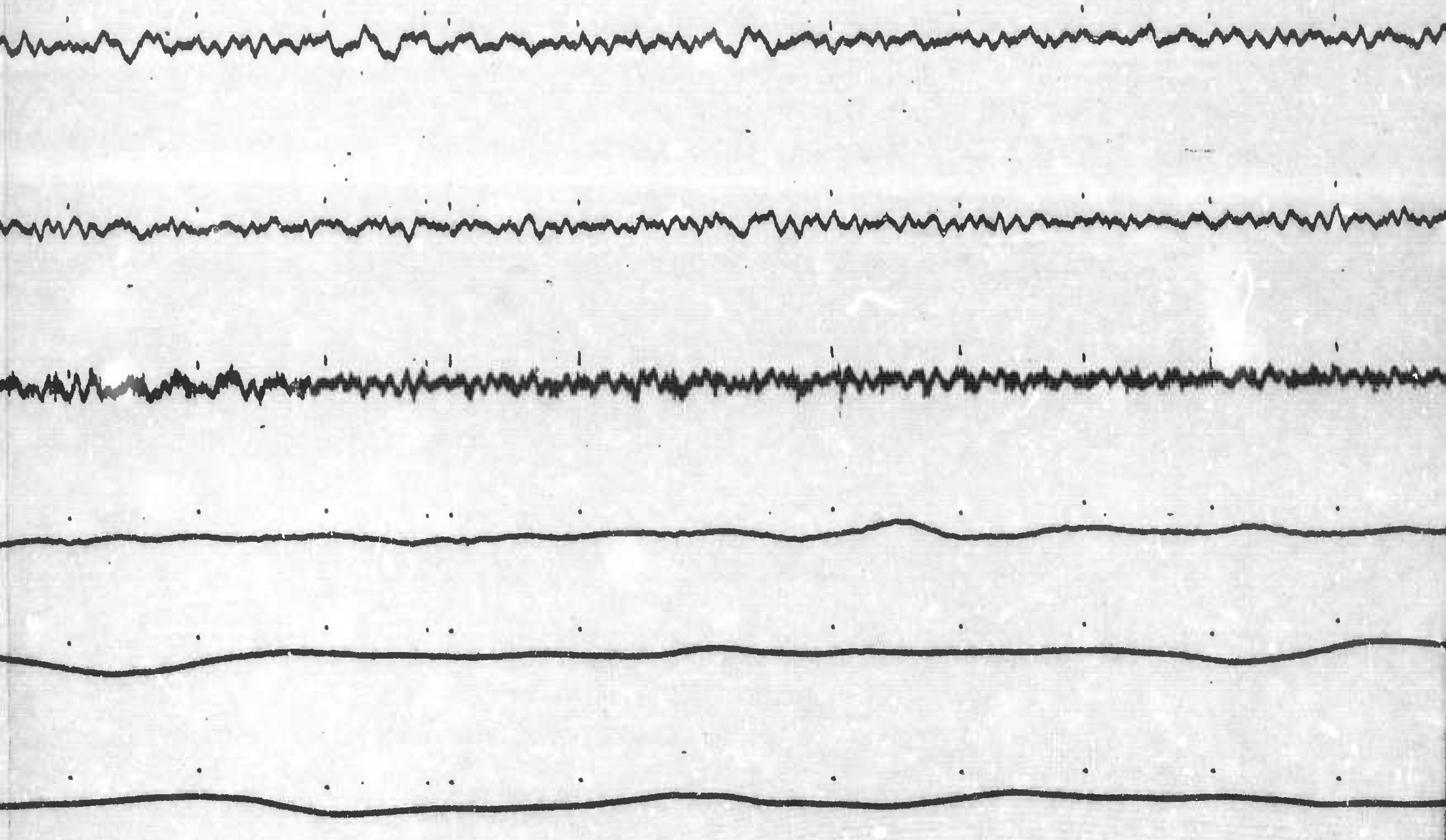

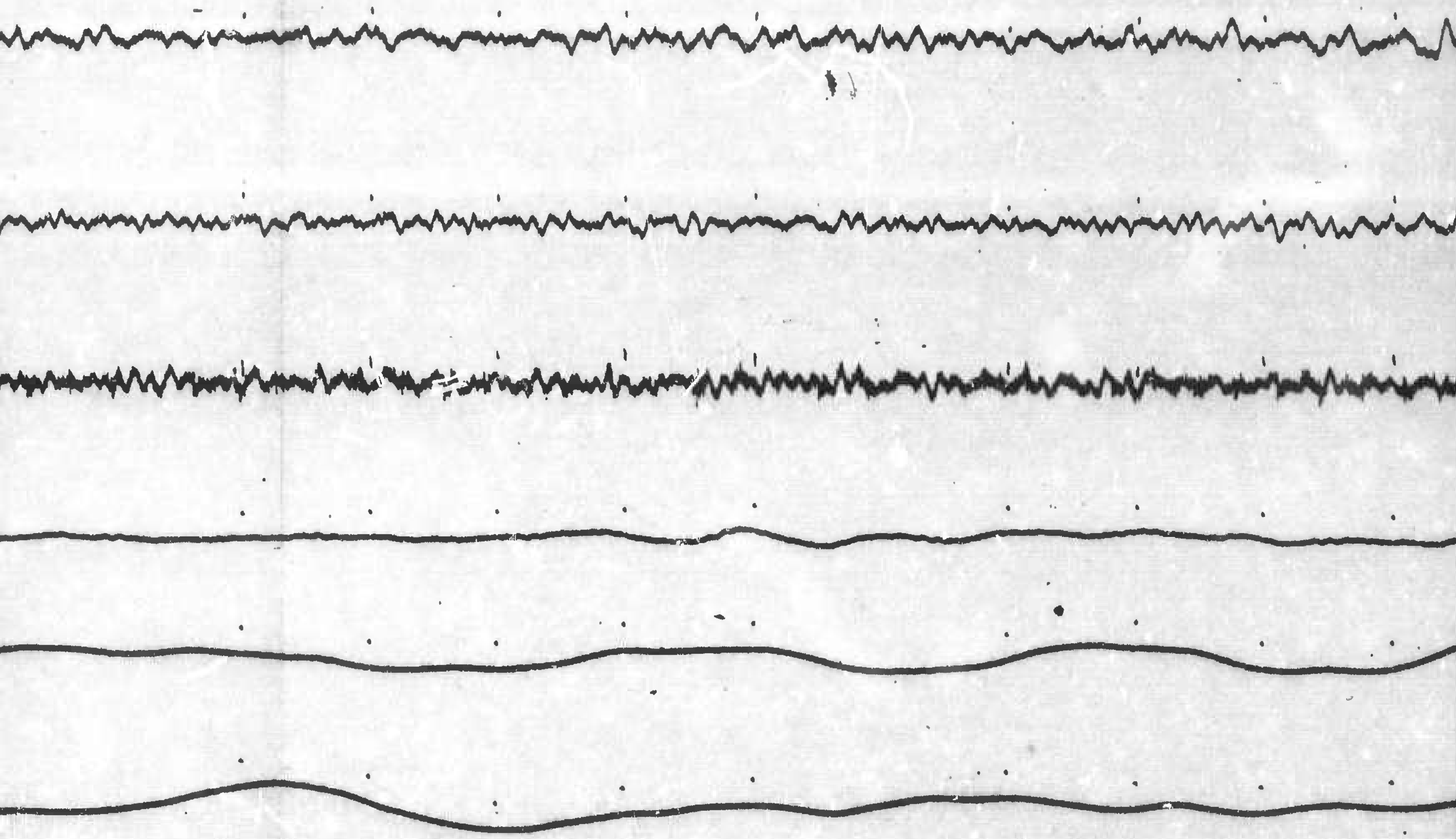

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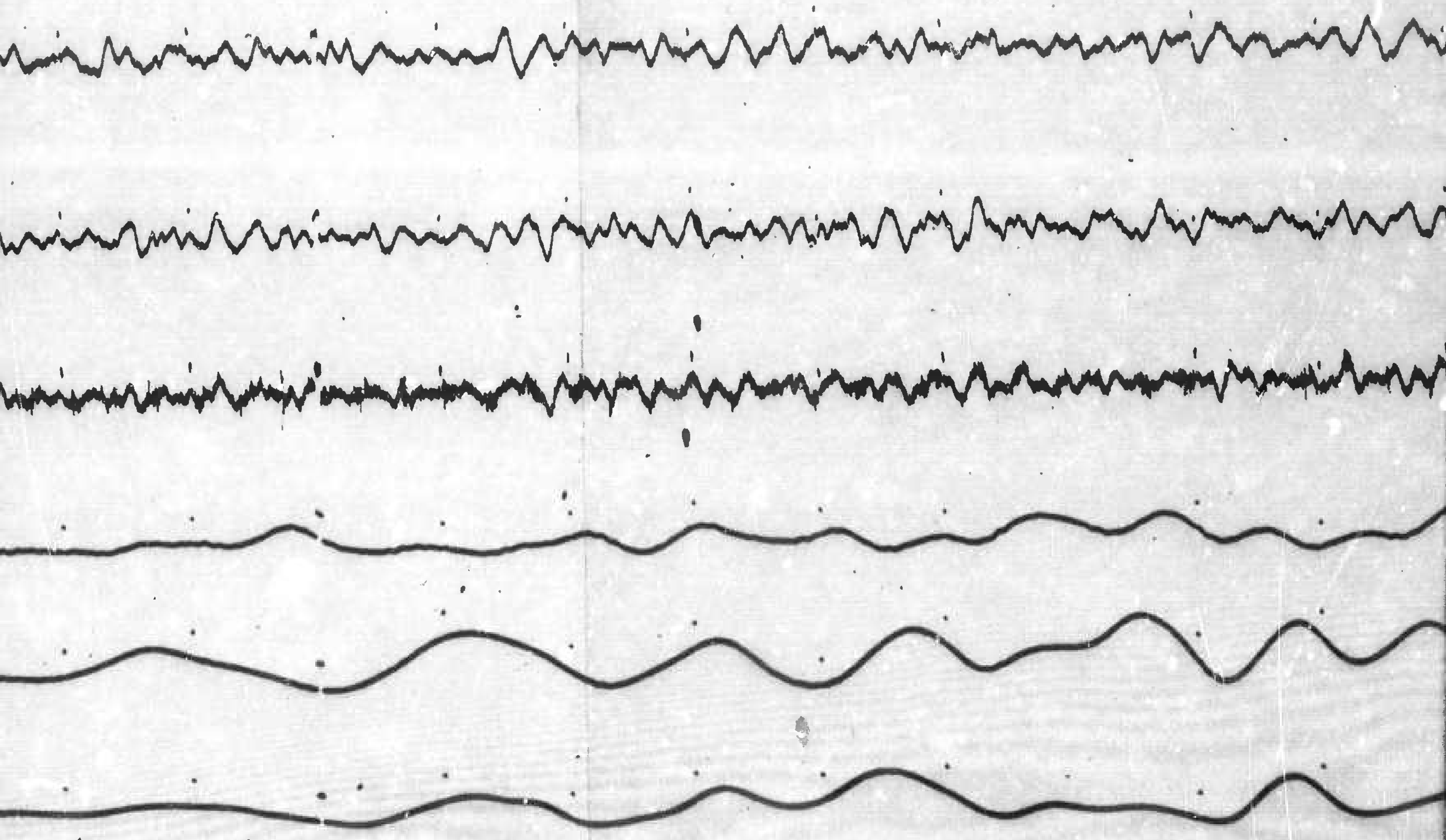

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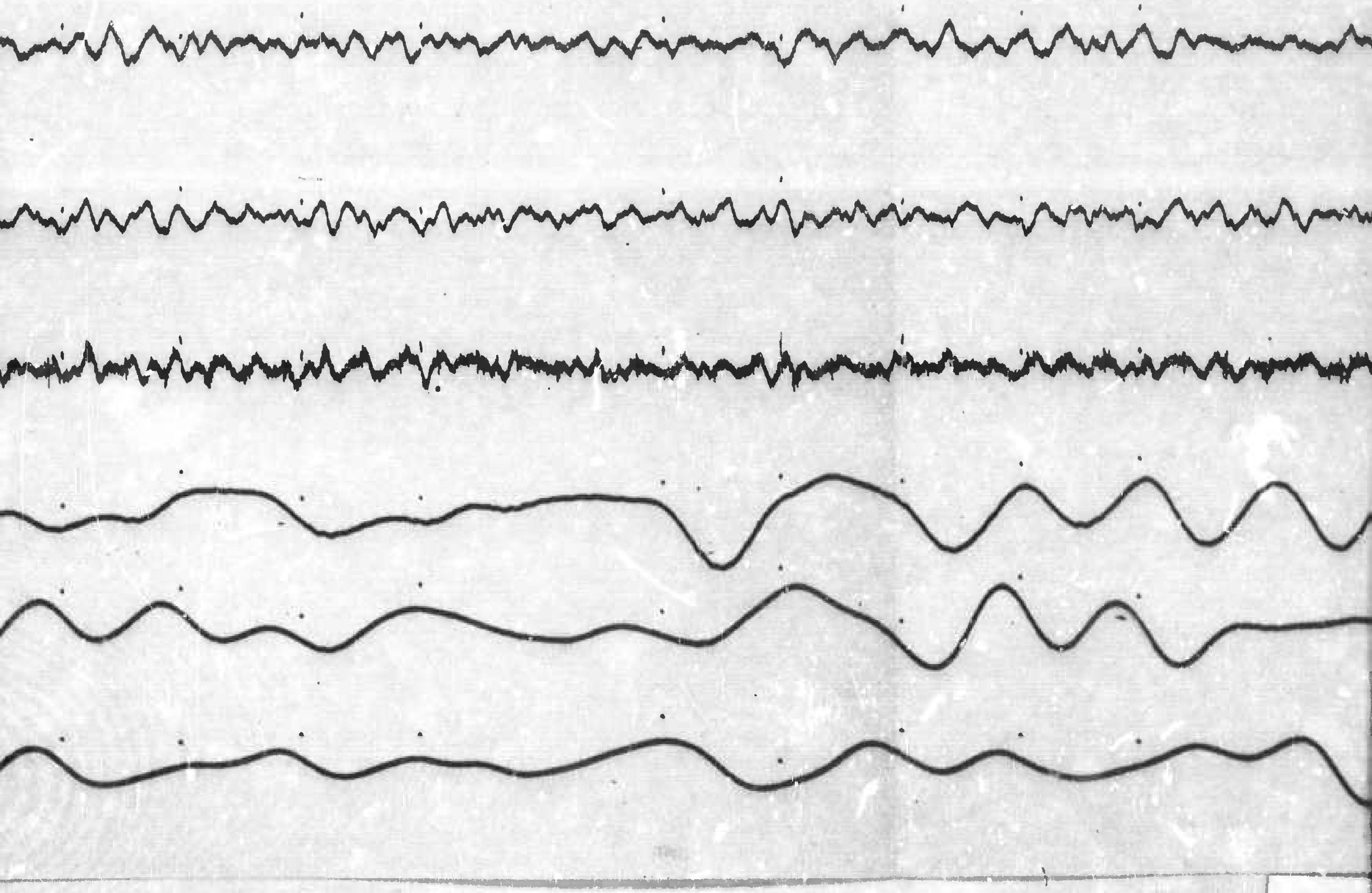

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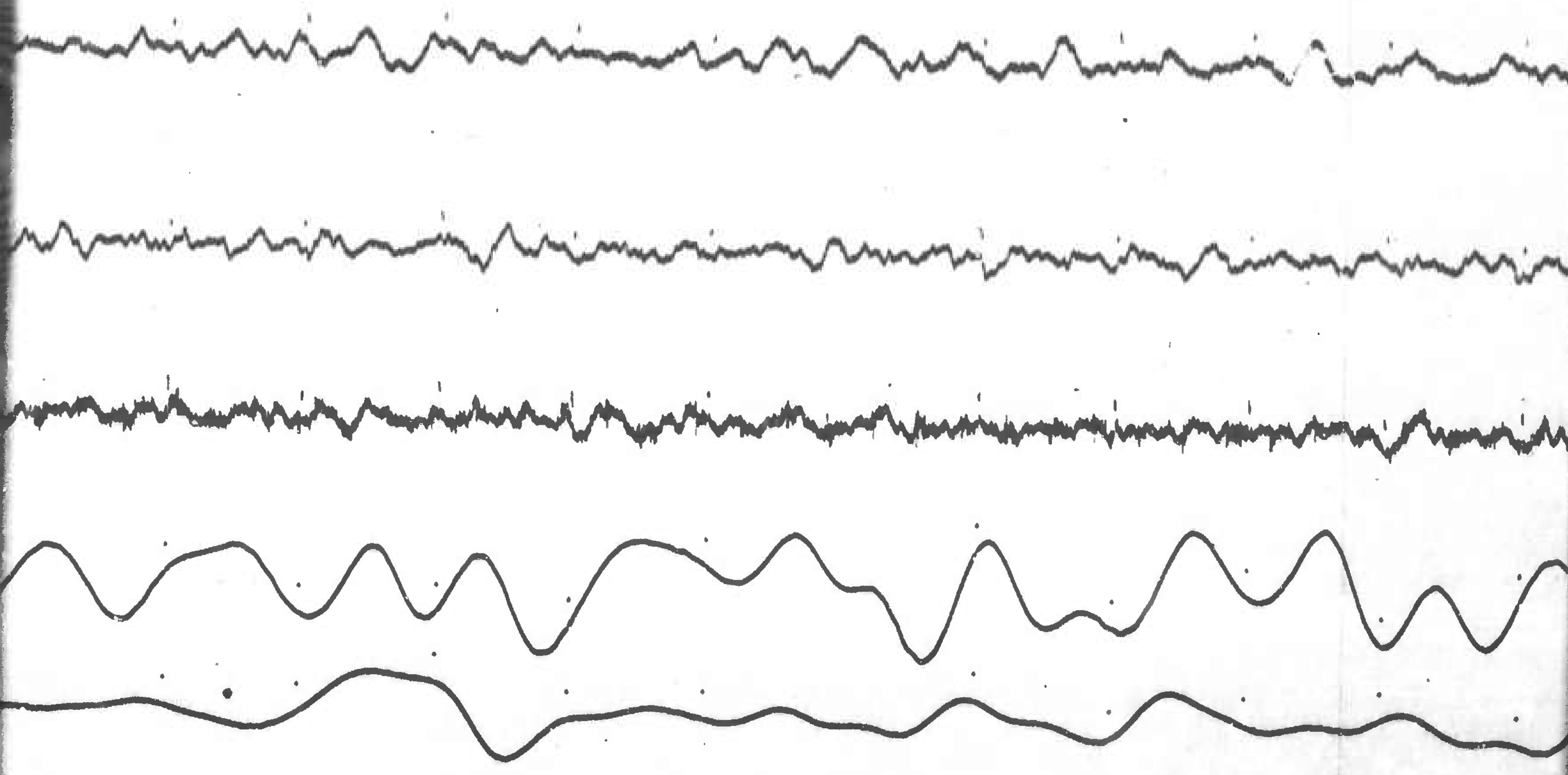

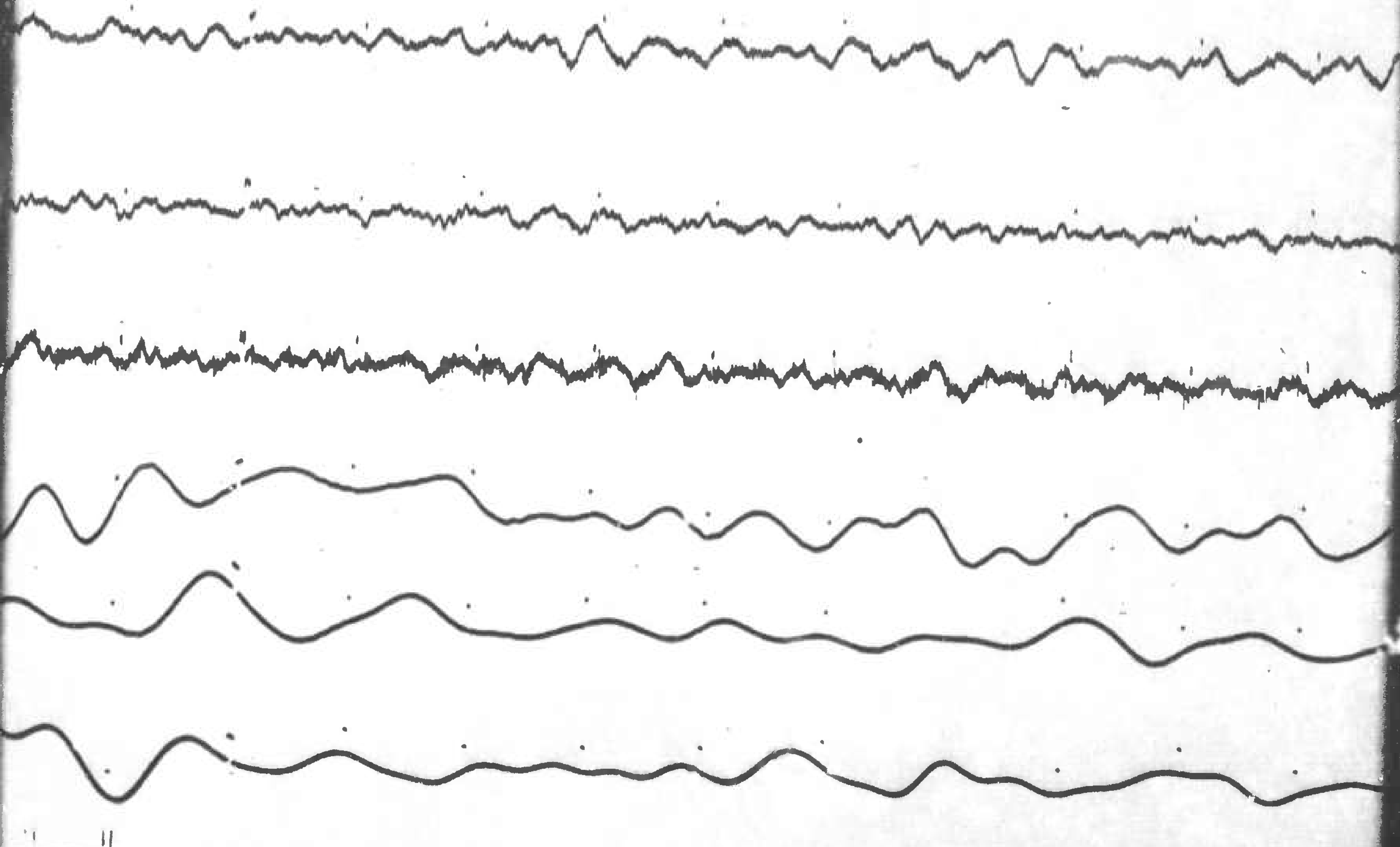

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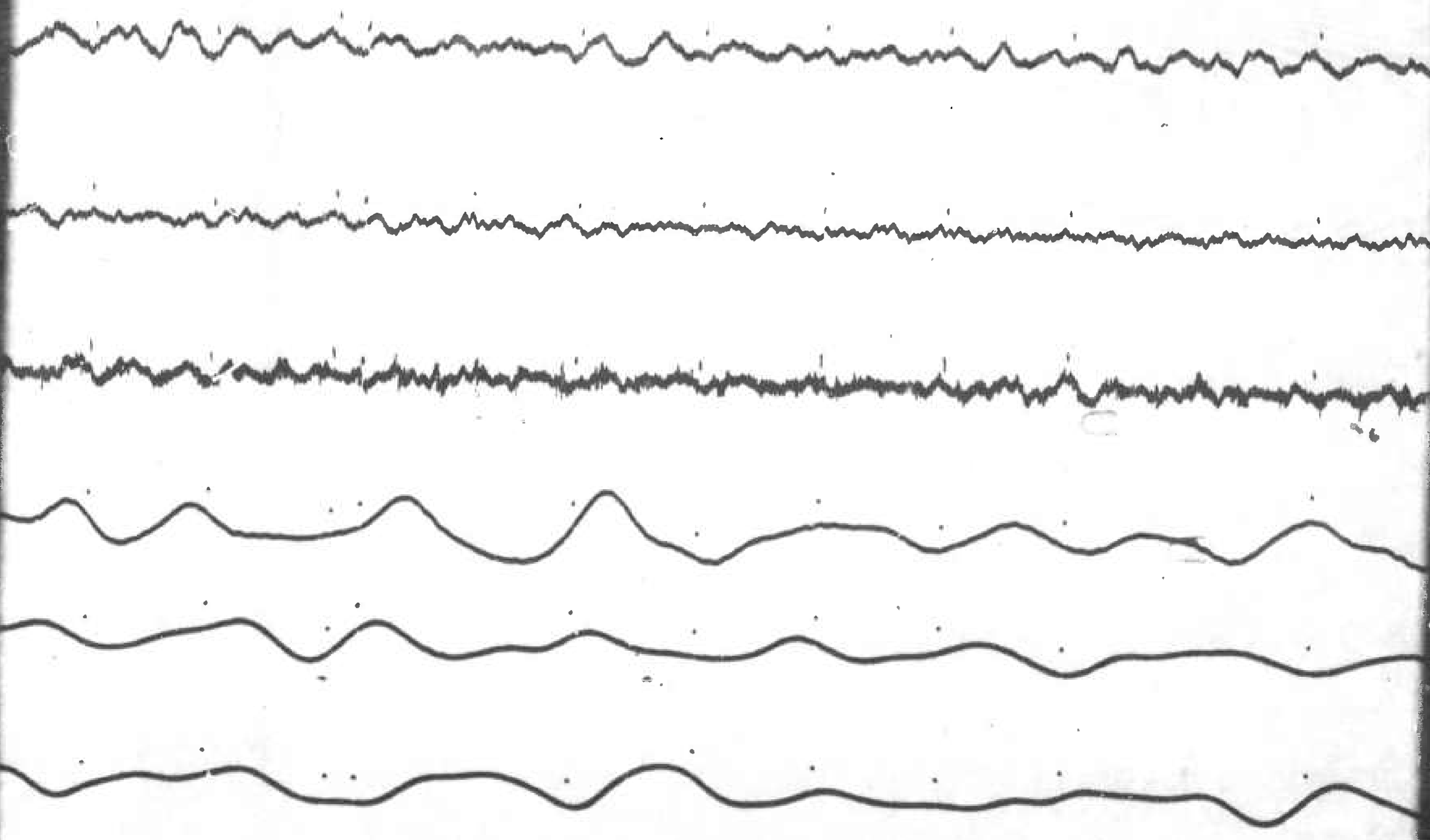

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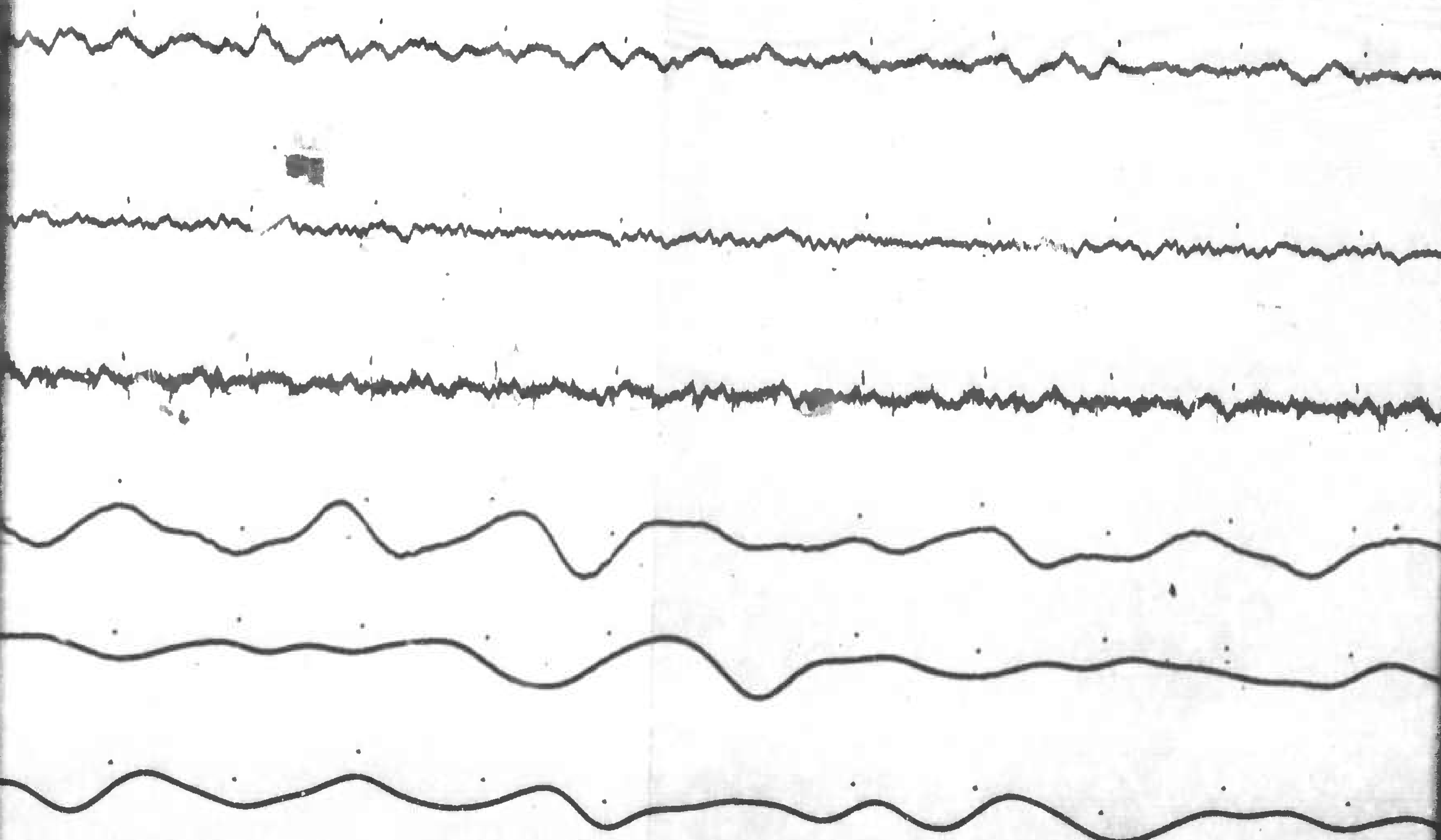

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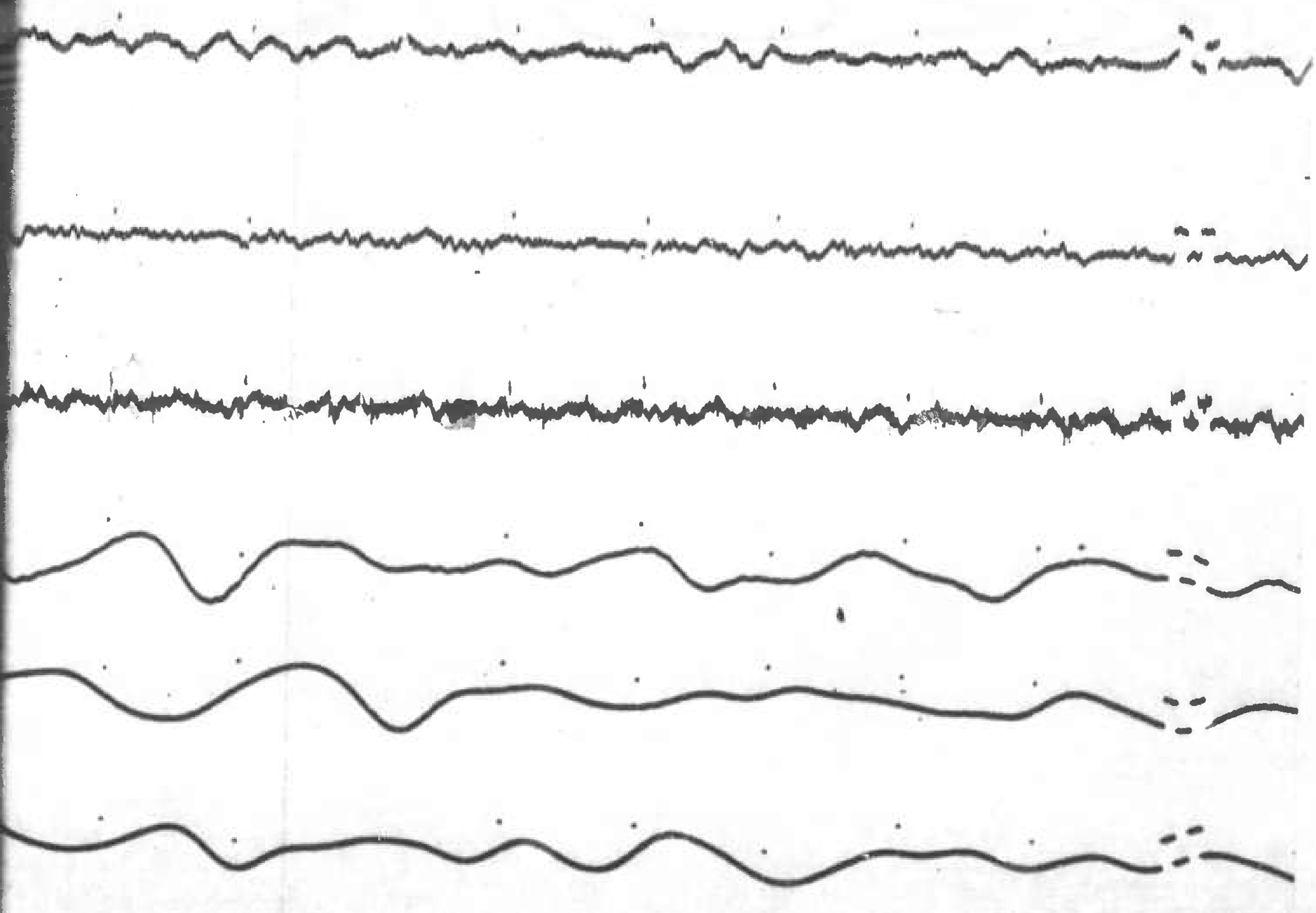

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